UMAN ANATOMY

(Descriptive and Applied)

BY

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Dedicated to

the sacred memory of my parents

FOREWORD

It is really a great pleasure for me to introduce "Human Anatomy" edited by my colleague, Dr. S. N. Sahana. I take this opportunity of congratulating Dr. Sahana for the splendid work which he has produced at the cost of a tremendous amount of labour, unthinkable for the resources of a single man.

When, at first, a few years ago, I heard that Dr. Sahana was writing a Textbook of Anatomy, I was diffident, because, myself being an author of a book, I had the experience of the magnitude of work in editing a scientific book. However, I am now convinced that this book, which is beautifully illustrated with numerous comprehensive diagrams, most of which are original from the actual specimens, fully justifies the merit of a Textbook of Anatomy. Moreover, some chapters in this book, such as those on General Introduction, Histology, Topographical and Radiographic Anatomy, are very novel and useful. The inclusion of an outline of the Histological techniques in the chapter on Histology is a new feature of this book. The other chapters, also, provide all necessary information. This would minimise the stress and strain of a medical student who will collect many a fact from various books to face the ever-increasing curriculum. I am glad to say that the birth of this book, which bespeaks the long teaching experience of the author, would fulfil the long-felt need for a Textbook of Anatomy by an Indian author.

I strongly recommend this book to students of Anatomy who would be amply benefited by it.

PREFACE

The magnitude of a book on *Human Anatomy* is, indeed, very great and it is a pleasure for me that, at last, against heavy odds, with continuous struggle for the last 24 years I have been able to place before students a complete *Textbook of Anatomy* under the title "*Human Anatomy*". I have no idea about the facilities of editing a textbook of such a magnitude in foreign countries, but it is still a difficult task for an Indian to accomplish it. For many a year, for hours and hours together I had to sit by the side of the artist to get only the diagrams completed and I have a feeling that I have laboured much but my labour would only be amply rewarded, provided the students, for whom the book is intended, appreciate the usefulness of this book.

This is on the whole, a *Systematic Anatomy*, both descriptive and applied, but for the convenience of students, a regional bias has always been given in places where it was thought necessary. The subject of Embryology has been treated both regionally as well as systematically and for this, some intentional repetitions have been made. Again, for the benefit of students, Topographical and Radiographic Anatomy have been dealt with together in a separate chapter. My close contact with the students of Anatomy for years has enabled me to understand their difficulties which are attributable to the progressive expansion of the subject of Anatomy and as such, I have spared no pains to minimise lengthy descriptions, but at the same time, I have attempted to make the subject easily understandable. The chapter on General Introduction has been made interesting as far as practicable. Histology has been treated, in part, in the chapter on Histology, and in part, along with the description of the individual organs or structures. A section on Histological techniques, as required by an under-graduate student, has been described briefly along with the chapter on Histology.

The volume has been profusely illustrated with about one thousand comprehensive diagrams of which many are in colours and much care and attention have been paid to this aspect of the subject. In most cases N. A. P. (Nomina Anatomica Paris, 1955) nomenclature has been used retaining the old ones in brackets.

In spite of all care and scrutiny some printing mistakes have crept in, for which I am really sorry, and I owe an apology to my readers.

I am much indebted to Prof. W. H. Hollinshead, Ph.D., Professor of Anatomy, Mayo Foundation, University of Minnesota for permitting me to reproduce some of the diagrams from his book, Anatomy for the Surgeons Vol. I, published by Messrs Paul B. Hoeber, INC.

I am glad to express my heart-felt thanks to my professor, Dr. M. L. Pan, M.B.B.S., L.R.C.S., F.R.C.S., for his encouragement and guidance in compiling his voluminous book and for writing a "foreword" on this book.

I beg to offer my sincere gratitude to the Director of Health Services, Govt. of Vest Bengal and to Dr. P. Bose, M.B.B.S., Professor of Anatomy, Calcutta Medical College, Calcutta, for permitting me to draw sketches and take photographs of some f the specimens from the Anatomical Museum, Calcutta Medical College, Calcutta.

I beg to offer my sincere thanks to Dr. K. K. Banerjee, M.B.B.S., Ph.D., Reader ı Anatomy, Calcutta Medical College, Calcutta, for lending me some of his histolocal slides for microphotography and for helping me with some notes on histological chniques.

I am thankful to Dr. N. Goswami, M.B.B.S., Ph.D., Reader in Anatomy and r. S. Mitra, M.B.B.S., Assistant Professor of Anatomy, N. R. Sircar Medical College, alcutta, for many valuable suggestions generously offered.

I am glad to express my sincere gratitude to Dr. H. Rakshit, D.Sc., Professor of Physics, Indian Institute of Technology, for contributing to the text on the fundamentals of 'X' Rays and their applications. I am also much indebted to Dr. R. K. Pal, M.Sc., M.B.B.S., M.R.C.P., D.Sc., Professor of Physiology, R. G. Kar Medical College, Calcutta, for revising the chapter on Histology and for lending me some of his histological slides. I am also much indebted to Dr. H. K. Chatterjee, M.B.B.S., D.A.E. (Paris), F.R S.M. (London), Head of the Dept. of Anatomy, University College of Medicine, Calcutta University, for revising the chapter on Embryology. I beg to offer my sincere gratitude to Dr. Bhupen Bose, M.B.B.S., Ex-Professor of Anatomy, R. G. Kar Medical College, Calcutta, for permitting me to do some special dissections in his department and to utilise the Anatomical Museum at R. G. Kar Medical College, Calcutta.

I beg to convey my thanks to Messrs Paul B. Hoeber, INC., Messrs W. B. Saunders Company, Philadelphia and London, and to Messrs Lederle Laboratories Ltd., for permitting me to reproduce some of the diagrams from their publications which have been duly acknowledged in appropriate places in this volume.

Thanks are also due to Dr. P. R. Deb, B.A., M.B.B.S., my colleague, for preparing some of the dissected joints and for his co-operation in preparing the chapter on Topographical Anatomy.

Thanks are also due to Sri Ranoj Kumar Nag and Miss Chitra Sen, my prosectors who have helped me in preparing some of the dissected specimens.

I am also grateful to my colleagues and well-wishers whose constant encouragement was a source of impetus for me for this vast work.

Thanks are also due to Prof. A. K. Sanyal, B.E., A.M.I.E. Bengal Engineering College, Howrah, for his active help in the designing of the microphotographic arrangements and to Dr. P. N. Chatterjee, B.E., Ph.D., for taking some of the microphotographs at B.E. College, Howrah.

I am also thankful to Dr. R. Dutta Gupta, one of my students for helping me in preparing the index.

Thanks are also due to Dr. Dwijapada Chatterjee, who has just left for England for higher studies, for doing the proof-reading of some of the designs.

I am much indebted to my publisher Messrs "The Central Book Agency", Calcutta, but for whose encouragement and help it would not have been possible to get this book published.

Further, I beg to offer my sincere thanks to my artist, Sri L. K. Roy, but for whose patience and skill the diagrams would not have been so nice and accurate.

I must also thank "Biswasri" Sri Monotosh Roy and Sri Satya Pal for allowing me to take a few snaps of their physical poses.

Last but not the least, I am much indebted to my wife who courageously faced many hardships owing to myself being heavily engaged in the preparation of the manuscript for long years.

AUTHOR

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HUMAN ANATOMY

HUMAN ANATOMY

GENERAL INTRODUCTION

The subject of Anatomy. Anatomy is the science which deals with the study of form and structure of any animal. When this study relates to human body we call it a Human Anatomy which is the subject matter in this book. When we think of Human Anatomy we must also think, that to learn it, we must have a set of bone, a dead body, and a good book to guide us. The subject of Anatomy is a vast one and it is impossible for any one to memorise all the facts related to innumerable structures of which the human body is made up, and in fact, it is not necessary. Therefore, no one should be scared off about the magnitude of the subject but he should try to learn how best the subject could be controlled leaving aside things of no practical importance.

Methods of Anatomical studies. The structures of which the human body is built up can be studied with unaided eyes by dissecting the dead body or by other methods, and such studies based on naked-eye impressions are included in *Gross* or *Macroscopic Anatomy*. Whenever we want to know about a structure in more detail beyond the scope of naked-eye vision we need the aid of a microscope, and the study of Anatomy with the aid of a microscope is known as *Microscopic Anatomy* or *Histology*.

The ways in anatomical methods. There are various ways in which the study of anatomy can be undertaken and for this, Anatomy can be subdivided into the following sub-groups to suit various methods of studies:

Anatomy

Living Anatomy	Cadaveric Anatomy	Embryology	Experimental Anatomy	Topographical Anatomy	Applied or Surgical Anatomy	Clinical Anatomy

THE LIVING ANATOMY. The field of the living anatomy is very much limited and the studies in living anatomy are incomplete without the knowledge of cadaveric anatomy. Therefore to study a particular structure, observations on both fields of anatomy must be correlated.

There are various methods by means of which anatomical studies can be carried out in the living body. The following are the usual methods in living anatomy:

Inspection. By simple inspection many a fact in anatomy can be correlated in the living body as for example, the form, shape and position of the clavicle or collar-bone can be ascertained by simple inspection at the root of the neck from the front. Similarly, by looking into the surface features, the form and position of a underlying bone or a muscle or the form assumed by a muscle during contraction, can be judged.

Palpation. By palpation or by feeling by the hands, the facts ascertained by inspection can be verified and a deeper structure unseen by naked-eye vision can be explored.

Percussion. This is a method in which by tapping on the surface of the body by fingers, as shown in the accompanying diagram, and by noting the difference in the tone of the sound the outline of an underlying viscus can be ascertained.

Auscultation. By hearing the sounds with the help of an instrument called stethoscope, the functions of some of the organs in our body can be understood.

The methods of percussion and auscultation are not usually practised in pre-clinical courses. However, they are widely practised in clinical courses.

Endoscopic examinations. There are some instrumental devices by means of which interior of some hollow viscera can be visualised and impressions al

their internal pattern can be gathered. Laryngoscope, bronchoscope, oesophagoscope, gastroscope, sigmoidoscope, proctoscope, urethroscope, cystoscope, etc. are instruments used for examining the interior of the larynx, bronchus, oesophagus, stomach, sigmoid colon, rectum, urethra and the urinary bladder respectively.

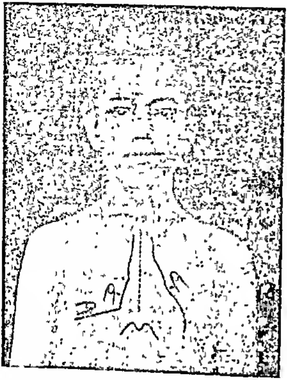


Fig. 1. Percussing out the margins of the heart and the upper border of liver.

Radiography or Radiographic Anatomy. With the improved techniques in radiography, the study of anatomy by X-ray or by Radiography is gradually growing in importance and it has been integrated in anatomy as a method of study. Many a fact in gross anatomy can be revealed and demonstrated in a skiagram, and some of the organs may be seen functioning through fluoroscopy (by looking into the screen on which shadows fall).

History of X-Ray. It is a well-known fact that a gas under normal conditions is a bad conductor of electricity. Under special circumstances, however, it can become conducting. For example, the insulation property of ordinary dry air at atmospheric pressure breaks down when it is subjected to very strong electric fields. If, however, the pressure be lowered to about a few thousandths of an atmosphere, then electric current can be made to pass through it even at comparatively low voltages. But when the gas pressure in a discharge tube is very much reduced, say down to about one millionth of an atmosphere, conduction takes place only under high voltages resulting in the emission of the so-called "cathode rays". Systematic studies on these rays, notably by Sir William Crookes, Sir J. J. Thomson and J. Perrin have led to the conclusion that they are electrons carrying negative electric charge.

The cathode rays were found to possess many interesting properties and rapidly attracted the attention of contemporary workers all over the world. W. C. Roentgen, while working in a dark room with his discharge tube covered with black paper observed that a screen of barium platinocyanide glowed brilliantly when brought near the tube. As a result of further researches he concluded that this was due to a new kind of invisible radiation which could pass through various substances, affect photographic plates and produce fluorescence in certain chemicals like barium platinocyanide. He also found that human skin and flesh are comparatively more transparent to these rays than the bone. So, interposing the hand between the tube and the fluorescent screen he could visualise the contour of the bones on the screen. In view of the unexplored nature of these rays—they were definitely different from the cathode rays—Roentgen designated them as X-rays. His

Fig. 2. Auscultating the heart.

discovery was announced in 1895 and within a very short time X-rays were being produced and studied in all the important laboratories of the world.

Uses. Although more than 55 years have elapsed since the discovery of X-rays, it is hardly possible to over-estimate their usefulness. X-rays are now *generally recognised as a very* powerful tool for investigating the atomic and molecular structure of materials. Their multifarious use in medicine for diagnosis and therapy, in biology and genetics are widely known. They also provide convenient methods of supplementing chemical analysis. *Furthermore, the industrial* application of X-rays is rapidly increasing. Various kinds of inspection jobs in the metal industry are now being carried out with the help of these rays which provide a suitable method for the non-destructive testing of irregularities in materials such as blow holes, cracks, etc. Consequently X-ray equipments of special construction are being increasingly harnessed to modern engineering workshops and shipyards, for fluoroscopic examination of packaged food products and for the detection of foreign matter such as nails in automobile tyres and many similar jobs.

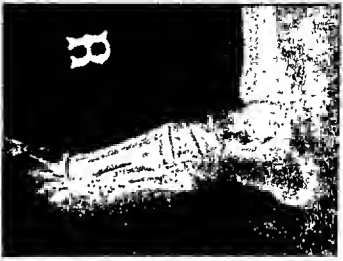


Fig. 3. Skiagram of foot.

Typical X-ray tubes of simple design

Figure 4 shows the diagram of a simple gas-filled tube which has been sealed off at P after the desired gas pressure has been attained. The concave aluminium cathode C focusses the cathode rays on a small region in the tungsten anticathode T which is connected externally to the anode A. There *is no provision for cooling of the target and as such the tube is not suitable for continuous operation* at high power. The tube is operated with high voltage of correct polarity making C negative and A positive. Recently gas tubes of special design have been produced which can be operated directly from a high voltage transformer without a rectifier. These are self-rectifying tubes.

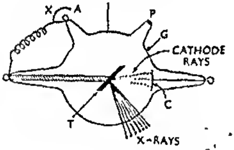


Fig. 4. A Simple gas filled X-Ray tube.

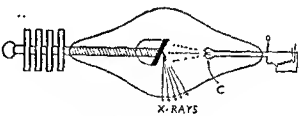


Fig. 5. A high vacuum X-Ray tube.

Figure 5 shows the diagram of a typical high vacuum type X-ray tube in which the cathode C is a tungsten filament which can be heated to incandescence by current from a battery by a suitable low voltage transformer. The electrons emitted by the cathode are attracted by the anode acting also as the *target maintained at a suitably high positive potential with* respect to C. The anode back-extension is provided with metal fins which dissipate by convection and radiation the heat generated in the target. The filament C is generally surrounded by a metal cup (not shown in the figure), which serves to focus the electrons into a beam.

Medical application of X-rays. The medical applications can be broadly divided under two categories, (*i*) for *diagnosis* including fluoroscopy and radiography and (*ii*) for *therapy* such as curing skin diseases and killing malignant tumors. As pointed out earlier, the basis of diagnostic radiology is the differential absorption of the part to be examined and the surrounding body matter. Diagnosis of bone fractures, diseased teeth, location of bullets, pins and similar foreign matter in the

body, stones in the kidney, detection of the first traces of tuberculosis, are some of the routine performances of radiography.

There is nothing like a lens of an optical camera in an X-ray diagnostic apparatus. In fluoroscopy or radiography we get only shadow pictures and for sharp definition and contrast the X-ray source must be as far as possible a point source. The specimen to be studied is therefore placed at some distance from the tube. For good contrast the wave length or tube voltage and exposure time should be properly adjusted depending upon the part to be examined and also upon the age of the person. The tube voltage and exposure are considerably less for a child than for an adult. Further, for fluoroscopic inspection, the tube voltages are usually higher than for radiography.

In regard to X-ray therapy it may be noted that the lethal effects of X-ray depend upon various factors. The dose also varies with the type of cell concerned. Very soft X-rays are widely used for treatment of various skin diseases like ringworm, eczema, etc. Deep-seated malignant growths are rather difficult to be treated, because of the harmful action of these rays on the skin which necessarily must be penetrated. Deep therapy, using very hard rays, is resorted to in such cases. The success of such a treatment depends upon the fact that abnormal growth like cancer may be destroyed by a suitable dose of hard rays which do not produce harmful effects on the surrounding healthy tissues.

Electromyographic tracing. This is a method in living anatomy in which by noting the action potential and electric fluctuation of a muscle or a group of muscles in a recorder instrument (electroencephalograph with electromyograph apparatus) the activity of a muscle or a group of muscles in a particular joint movement can be determined.

Normally, an ordinary muscle with minimum contraction can produce an electric fluctuation, 20-30 per second, and voltage of 0·2-2 millivolt. With stronger contraction the frequency and voltage rise. Thus from the study of electric fluctuation and voltage during a particular movement the activity of each muscle can be determined

The apparatus used for this purpose is an eight channel electroencephalograph cum electromyograph. An air-conditioned, sound-proof room with a temperature of 75° to 80°F is necessary for such examinations. The subject in whom the examination is to be conducted, should wear a light dress and should use a light weight as a resistance in a particular movement in which the activity of a muscle or a group of muscle has to be determined. For recording purpose both surface and co-axial needle electrodes are used. The surface electrode is placed over the surface of a particular muscle and the co-axial needle is inserted into the muscle fibres. The surface electrodes give a general survey of the whole muscle whereas the co-axial needle electrodes give an estimate about the activity of a small group of muscle fibres. The action potential and frequency of individual muscle or a group of muscles during various phases of contraction are noted and the muscular activity may thus be evaluated. In case of deep muscles only the needle electrodes are used.

CADAVERIC ANATOMY. Our knowledge in anatomy is based mostly on studies on the cadaver or the dead body. In cadaveric anatomy the study of the structures may be taken up in two ways, *systematically* and *regionally*.

Systematic Anatomy. In systematic anatomy, depending on the functions, the whole body has been divided into different systems and the structures those are concerned to subserve a common function, however varying they may be, are grouped together in a particular system for their study. Thus the human body has been divided into the following systems:—

(1) *Locomotor system:* This system is mainly concerned in locomotions or movements and the structures concerned in movements are bones and cartilages,

muscles and joints and thus the locomotor system has further been sub-divided as follows:

(a) *Osseous or skeletal system or osteology.* This part of anatomy deals with the various bones and cartilages that build up the human skeleton.

(b) *Muscular system or myology.* In this section all the muscles of the body have been grouped together for their study.

(c) *Articular system or arthrology.* This is the section that deals with all the joints of the body.

(2) *Visceral system or Splanchnology.* In this system all the viscera, except the heart with the blood vessels, which has been included in cardio-vascular system, have been grouped together. The visceral system has further been subdivided into the following sub-groups:

(a) *Alimentary system.* In this system the alimentary canal (beginning from the mouth upto anus) together with the associated glands such as salivary glands, liver, pancreas etc., has been included. This system is mainly concerned in ingestion, digestion and absorption of food and elemination of non-absorbable residue as stool.

(b) *Respiratory system.* This system consists of lungs and the associated air passages namely nose, pharynx, larynx, trachea or windpipe, bronchi and bronchioles. This system is mainly concerned in gaseous exchange, and works rhythmically in inhaling (inhalation or breathing in) and exhaling air (expiration or breathing out).

(c) *Endocrine system.* In this system different ductless glands have been included. These glands secrete chemical substances known as hormones which have profound influence on the body mechanics.

(d) *Urogenital system.* Consists of urinary and genital organs. The urinary system consists of kidney, ureter, urinary bladder and urethra and is concerned in elimination of waste products in the form of urine. The genital system differs in the two sexes; in male, it consists of testes and their ducts, vas deferens, prostate, seminal vesicles and penis, and in the female, ovary, uterine tube, uterus, vagina etc. and are concerned with reproduction.

(3) *Cardio-vascular system or Angiology.* In this system the heart with the blood vessels and the lymphatics have been grouped together.

(4) *Nervous system or Neurology.* It is that part of anatomy which deals with the brain, spinal cord and the various nerves. It is subdivided into central and peripheral nervous systems. The central nervous system consists of brain and the spinal cord whereas the peripheral nervous system is further subdivided into somatic nervous system and autonomic nervous system. The autonomic nervous system has sympathetic and parasympathetic components which are concerned in controlling the visceral activities.

(5) *Integumentary or cutaneous system or dermatology.* This system deals with the skin with its appendages, that is, hairs, nails, sweat and sebaceous glands.

(6) *The organs of the special senses.* That is, the organ of vision, hearing, smell and taste, have been dealt with separately.

Regional Anatomy. In regional anatomy various structures of a particular region of the body are studied together with their relation to one another. As for example, when we study the region of the forearm, we read about the bones, muscles, vessels, nerves, lymphatics, joints etc. which are found in the region of the forearm. In regional anatomy, the whole body is subdivided into five regions, namely, head and neck, superior extremity or upper limb, thorax, abdomen, inferior extremity or lower limb.

EMBRYOLOGY. It is that part of anatomy which deals with the development of the embryo from the stage of fertilisation upto the end of prenatal life. The study of embryology, during the earlier stage, consists mostly of histological methods, and during later stage, both histological and macroscopical methods are used.

Comparative anatomy. It is that part of embryology which deals with the comparative study of gross anatomy and embryology of animals and man. Such studies explain many a fact in anatomy and is essential for better understanding of the subject and its evolutionary history.

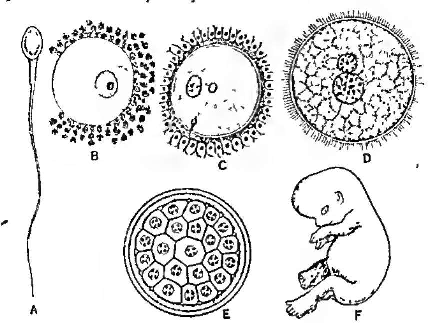


Fig. 6. Diagrams to show some of the embryological events
A=Spermatozoon (Male sex cell) ; C=Union between male & female sex cell ;
B=Ovum (Female sex cell) ; D=Zygote , E=Morula ; F=Foetus.

Experimental Anatomy. In order to study the functions, growth and behaviour of a particular tissue in normal and abnormal conditions experiments are done on various ways, and such studies come under the purview of experimental anatomy. In this observations are made in living animals or living tissues by following some experimental techniques, as for example, the *transparent chamber experiment.* In this experiment a puncture is made in a rabbit's ear which is fixed between two transparent celluloid plates and is examined under a microscope to note the reparative processes and other physiological activities of living cells. Homogeneous or heterogeneous grafting of tissues, transplantation of structures, tissue cultures etc. are other fields of work in experimental anatomy.

Topographical or Surface Anatomy. Recognition and palpation of anatomical landmarks such as, bony prominences, muscular elevations etc. and representation of the outline of viscera or other structures on the skin surface are included in topographical or surface anatomy. By the study of topographical anatomy we may have an estimate about the location of a particular structure in relation to the skin and thus it helps in approaching the structure, when necessary, from the skin without much disturbing other tissues. Moreover, bearing in mind the normal outline, any change in position of a particular organ may also be determined, or the source of some of the pathological conditions may be linked up with a particular organ or structure by studying its surface relation.

Applied Anatomy. While doing surgery or practising medicine or its other branches anatomical facts are correlated for the sake of successful operations or treatments. Such studies are not only essential for better understanding of some of the pathological conditions but they are also helpful in diagnosis and treatment.

Clinical Anatomy. Keeping in view the impressions about the normal anatomy it would be interesting to note the changes in abnormal conditions (diseases), and when some of the clinical conditions are examined and are compared with the

condition in normal anatomy we call it a clinical anatomy. As an example, a case of nerve paralysis may be mentioned. Whenever a student with his knowledge of anatomy of a particular nerve gets the opportunity of examining a case of the same nerve paralysis he will be able to correlate his anatomical knowledge with the clinical condition involving the nerve. This will give him a better impression about the functions of the same nerve and would create more interest in his studies. Similarly palpation of the inguinal canal and examination of a case of inguinal hernia will create more interest in a student in his studies on the anatomy of the inguinal region.

Fig. 7. Palpating the inguinal canal.

Minute or Histological Anatomy. In histological anatomy tissues after necessary preparations are examined under a microscope and details of the cells and intercellular structures are noted.

Preparations necessary for examining the tissues for microscopical study, or histological techniques, are elaborate and painstaking, and it is beyond the scope of this book to go into details of all these techniques. However, considering the needs of a undergraduate student some of these techniques have been described briefly under *"Histological techniques"*.

Fundamentals of Anatomy. With what amount of knowledge an individual is capable of acquiring a sound foundation in the subject of anatomy, is a question difficult to be answered. However, I consider the following to be important in respect of the fundamentals of anatomy.

(*a*) One should know about the general plan of construction in each system and should possess a fair knowledge about the workings of such system.

(*b*) A fair knowledge about the tissues of the body is an essential prerequisite to sound fundamentals in the subject of anatomy.

(*c*) Moreover, it is known, that the knowledge of anatomy ripens then only when the knowledge of physiology is added to it and therefore, anatomy and physiology should be read together or at least definite co-relation should always be maintained in the study of these subjects.

(*d*) Further, it seems that regional study, in most cases, is more suitable for the beginners than other methods and for this, bones and soft parts should be read together as far as practicable for a better foundation.

(*e*) Lastly, but not the least, methodical dissection is the key to the fundamental knowledge in Anatomy and every one should stick to it with all care and patience.

Dissection as a method of Anatomical study. Dissection on the dead body is an old method and it still stands the test of time and in India this is the method most widely practised for studying the subject of anatomy. By dissection the disposition of gross structures can be displayed well and the impression gathered therefrom is not far from what is seen actually in the living body except for minor deviations of less practical importance.

To the dissector. To do dissection on any part it is the duty of the dissector to acquire full first hand knowledge about the structures in the part to be dissected, and unless one follows this truth, it is sure, that he would be disappointed at the expense of his labour and energy, because without full knowledge about the structures beforehand no one is sure what damage the point of the scalpel will do. Experienced anatomists recommend that before undertaking the dissection, the student, first of all, must acquire full knowledge about the bones of the part to be dissected; he must also know about all other structures to be found in the part and at the same time, he should have fair knowledge about the topography of the main structures of the part. Only after acquiring these knowledges he should proceed to know about the recognised lines of incisions and methods of approach to the structures step by step, and after then he should actually start the dissection. While dissecting he should display the structures individually as far as practicable, identify them, and study their course and their relations to the surrounding. He should also know about the functional significance of such structures in the part and the effects of their implication in diseases.

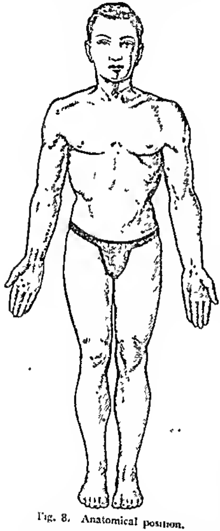


Fig. 8. Anatomical position.

The plan in this book. There are numerous books on the subject of anatomy by various authors, mostly foreign authors of monumentous work on the subject to their credit. These different authors have dealt the subject variously to suit the needs of varying grades of students. The general outlay in this book has been planned on a systematic basis. As both regional and systematic studies have advantages and disadvantages, in treating this book I have attempted to combine both wherever possible, with a view to presenting to the students the best of the both and thus, embryology has been treated separately as well as reginnally, while the topographical anatomy has been included in a separate chapter for the sake of continuous study which is considered necessary by the examinees. The histology has been treated partly in a separate chapter and in part with individual organ.

Anatomical Terminology. In order to prepare a nomenclature for all recognised structures, Anatomists from different parts of the world, with continuous efforts, have been able to establish a nomenclature agreeable to all concerned. While reading a book on anatomy the reader will frequently see the word "B.N.A." after the name of a structure. The word "B.N.A." stands for "Basel Nomina Anatomica". This has been adopted in memory of the Anatomical Commission of Nomenclature that met at Basel, Switzerland, in 1895. The "B.N.A." Commission formulated new nomenclature in place of the old ones which were thought to be unscientific by reasons of their having named after the name of the discoverer. Further revision of "B.N.A." nomenclature was done at an international congress of anatomists held at Bermingham in 1933. This revised nomenclature which is popularly known as "Bermingham Revision" or in short, "B.R." is still in vogue and is indicated after the name of a structure by the world "B.R.".

Anatomical position. This is the position of the body chosen by the Anatomists for descriptive purposes and for this, the human body is regarded as standing erect with eyes looking forward and arms by the side with the palm of the hand directed forward.

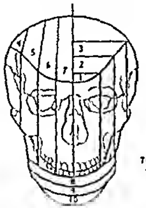


Fig. 9. Anatomical Planes

ANATOMICAL PLANES. In order to study the relations of the deeper structures of a particular part section is made through the part and the line of section is known as the plane of section. The following are the different planes through which sections are made for anatomical studies.

Sagittal plane. Any vertical, antero-posterior plane, (including the median plane), that runs parallel to the sagittal suture of the skull, is known as the sagittal plane.

Coronal or Frontal plane. Any vertical, side to side plane that cuts the sagittal plane at right angle, is known as the coronal or frontal plane. It runs almost parallel to the coronal suture of the skull.

Transverse plane. Any plane that cuts the long axis of the body or part of the body at right angle is known as the *transverse* plane.

Anatomical relative terms. Taking the anatomical position as a guide descriptive terms are used according to the relation of the structure to its environment and the following are the terms commonly used.

Anterior—looking forwards or towards the front.

Posterior—looking backwards or towards the back.

Superior—looking upwards or above or higher or more cephalic.

Inferior—looking downwards, or below.

Medial—nearer the median plane or nearer the middle line of the body.

Lateral—away from the middle line of the body.

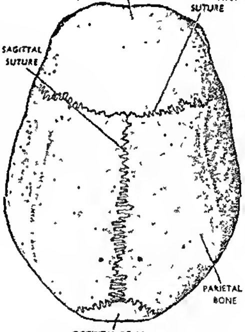


Fig. 10. Top view of human skull to show Sagittal and Coronal Sutures.

Anatomical relative terms used both in man and animal

Ventral. In human body it is described to denote "towards the front of the body" or "towards the belly" of the body, but in animals it means differently to denote "looking downwards" because the "belley" in animals looks downwards.

Dorsal—reverse to that of ventral or towards the back.
Cranial—close to the head or headwards.
Caudal—away from the head or tailwards.
Rostral—same as cranial.

In the limbs the following terms are used with reference to proximity of any structure either nearer to the trunk or further from the trunk.

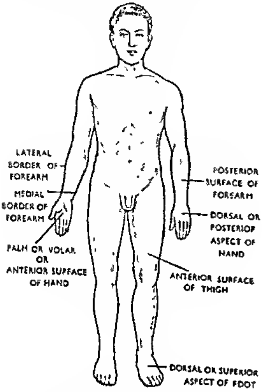


Fig. 11 Diagram of a human body to explain some of the anatomical relative terms.

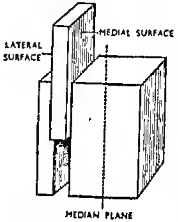


Fig. 12. Diagram to explain the terms "medial and lateral".

Proximal—nearer to the trunk.
Distal—away from the trunk.

Certain terms are used in respect of the hand and the foot only, such as *palmar or volar* (pertaining to the palm of hand) in the hand, and the *plantar* in the foot.

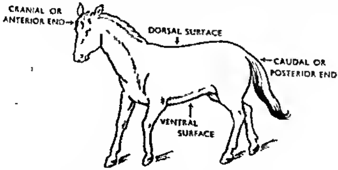


Fig 13. Diagram of a horse to explain anatomical relative terms used both in man and animal.

The term "palmar" or "volar" is synonimously used with the term "anterior" in description of the structures of the hand. Similarly the term "plantar" (pertaining to

the sole of the foot) is used synonimously with the term "inferior" in description of the structures of the foot. The common term "dorsal" used in description of the structrues of the hand and the foot, means reverse to that of palmar and plantar.

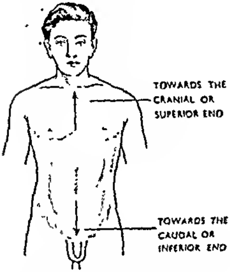


Fig. 13A. Diagram of a man to explain anatomical relative terms used both in man and animal.

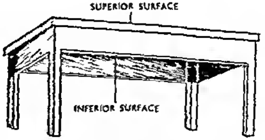


Fig. 14. Diagram of a table to explain superior and inferior surfaces.

Other terms:

Interior—Inside.
Exterior—Outside.
Invagination—Inward bulging of a wall of a cavity.
Evagination—Outward bulging of a wall of a cavity.
Superficial—Nearer to the skin.
Deep—Further from the skin.

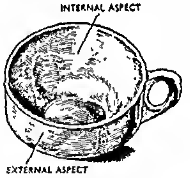


Fig. 15. Diagram of a cup to explain the terms interior and exterior.

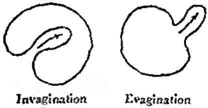
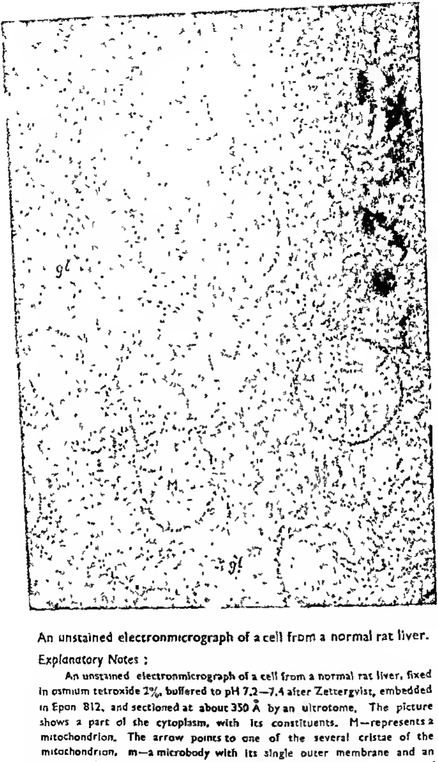


Fig. 16. Diagram to explain invagination & evagination.

Pre-axial and post-axial borders. The borders which separate the anterior and posterior surfaces of a limb are called pre-axial and post-axial borders with reference to their relationship with the original axis of development of the limb bud. The pre-axial border faces cranially whereas the post-axial border is directed towards the caudal end. In both the upper and the lower limbs the first digit, that is, the thumb in the upper limb and the great toe in the lower limb, corresponds to the pre-axial border. The opposite border in each case corresponds to the post-axial border.



An unstained electronmicrograph of a cell from a normal rat liver.

Explanatory Notes ;

An unstained electronmicrograph of a cell from a normal rat liver, fixed in osmium tetroxide 2%, buffered to pH 7.2—7.4 after Zettergvist, embedded in Epon 812, and sectioned at about 350 Å by an ultrotome. The picture shows a part of the cytoplasm, with its constituents. M—represents a mitochondrion. The arrow points to one of the several cristae of the mitochondrion, m—a microbody with its single outer membrane and an electron dense inclusion, believed by some to be the precursor of mitochondria. E.R.—the endoplasmic reticulum with its attached ribonucleo-protein particles. gl—shows the glycogen areas—distributed heterogenously over the cytoplasm. (magnification—X 50,000).

[To face page 13]

By courtesy of Dr. Tapan Mukherjee
Chittaranjan National Cancer Research
Centre, Calcutta.

Mitochondria. They are granular, rod-shaped or filamentous bodies within the cytoplasm and are capable of motile movements. They undergo segmentation or occasionally they reunite together within the cytoplasm and are believed to be concerned in the production of intracellular substances, such as enzymes, etc.

Vacuoles. They are structureless empty areas within the cytoplasm and may be temporary or permanent. This is often called the "Little stomach of the cell" in which processes of digestion and assimilation take place. When a foreign body enters into the cell, vacuoles surround the foreign body which helps in destroying or digesting the foreign body. Vacuoles also occur in certain degenerative changes of the cell.

Metaplasmic inclusion. They consist of granules, the products of secretion and excretion of the cell, which are temporarily stored within it until they are eliminated by excretion, and food droplets in the form of glycogen, fatty substances and other food elements.

Granules are permanent constituents of the cell protoplasm and chemically are compounds of protein in the form of nucleo-protein, glycoprotein etc. In the living cell the granules are in a state of constant vibratile movement known as the *Brownian movement*. These granules have varying staining reaction, *i.e.* granules of some cell have staining affinity for acid dyes, some for basic dyes and some for neutral dyes. On this basis of staining reactions the cells have been classified as follows:

(*a*) *Oxyphil* or *acidophil* or *eosinophil cells*—having staining affinity for acid or protoplasmic dyes.
(*b*) *Basiphil*—having staining affinity for basic or nuclear stain.
(*c*) *Neutrophil*—having affinity for none.
(*d*) *Amphophil*—having equal affinity for both basic and acid dyes.

Cell Division. Cellular reproduction takes place through division of cells in which one mother cell divides into two daughter cells, each of which again divides into two, and so on multiplication goes on until full growth is attained. The process of cell division is an intricated intra-cellular change which differs in details in case of somatic (cells that build-up the body) and germ cells (cells concerned for the continuation of the progeny). In case of somatic cells reproduction takes place in two ways, by *amitosis* and by *mitosis* or *karyokinesis*. In case of germ cells reproduction occurs in a different way. At first the germ cells multiply by the process of mitosis and then during their maturation (maturation division) reproduction occurs in two other forms which go by the name *heterotypical mitosis* or *meiosis* and *homotypical mitosis*.

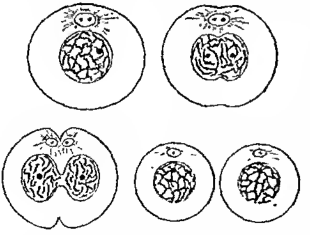


Fig. 18. Amitotic cell division.

Thus the methods of cell division can be discussed under (*a*) Amitosis, (*b*) Mitosis, (*c*) Heterotypical mitosis or *meiosis* and (*d*) Homotypical mitosis.

Amitosis. The amitotic cell division is a rare phenomenon in human subject and except perhaps in cases of giant cells of the bone marrow and the epithelial cells of the urinary bladder and the leucocytes, this method of cell division is seldom found to take place normally. Under some pathological conditions amitotic cell division is occasionally found to occur and therefore it is often presumed as a degenerative process rather than the healthy process of cell division which determines cellular activity and growth.

This is a simple method of cell division in which the nucleus at first shows signs of constriction which gradually deepens and then the cell body shows similar

change and the two cleavages meet together and the cell ultimately divides into two daughter cells.

Mitosis or Karyokinesis. Mitotic cell division is the usual mode of cellular reproduction in case of somatic cells and is a complicated elaborate process by which the mother cell is split into two daughter cells. The intense cellular activity and the series of changes that take place during the process of cell division, can be grouped under four phases namely, *prophase, metaphase, anaphase* and *telophase.*

Prophase. In this stage the centrosome divides into two, the nuclear membrane and nucleoli disappear and the chromosomes arrange themselves in pairs of homologous chromosomes, one of paternal, and the other of maternal origin, in the equator of the achromatic spindle.

The centrosome at first divides into two daughter centrosomes which diverge from each other so that each daughter centrosome moves to a pole diametrically opposite to the other.

Simultaneously with the movement of the daughter centrosomes cytoplasmic changes give rise to the formation of achromatic fibrils which extend from one daughter centrosome to the other and are arranged in the form of a spindle known as the *achromatic spindle.* Within the cytoplasm around each of the daughter centrosome fibrils are also found to radiate in all directions so as to resemble a star with radiating beams of light and such a star-like formation is known as *aster.*

With the above, the nucleus also shows remarkable changes. The nuclear membrane and the nucleoli disappear and the chromatins re-arrange and re-orient themselves in special formations. The chromatins which remain throughly dispersed within the nucleus during the resting phase of the cell (when the cell does not divide) are collected into small masses of nodules known as the *chromomeres.* The chromomeres are connected with one another by filamentous processes so as to form a series of chains of chromomeres known as *chromosomes.* The chain of chromosomes become intermingled with one another and are twisted variously so as to resemble a ball of thread known as *skein.* Simultaneously they become gradually condensed together so as to form a mass in which the individual chromomere is no longer detectable. The mass of chromosomes later on re-arrange in pair of homologous chromosome (one of maternal origin and the other paternal) either in the form of *rods, hooks* or *V-shaped angles* and are collected into the equator of the achromatic spindle so as to form the *equatorial plate. With the formation of the equatorial plate the prophase part of the mitotic division ends.*

Metaphase. During this phase each chromosome splits longitudinally into two so that the number of the chromosomes is doubled. The daughter chromosomes remain attached to the achromatic spindle and they re-arrange themselves in such a way so that half the chromosomes remain connected with one centrosome through the achromatic spindle and the remaining half to the opposite centrosome. *With the complete division of the chromosomes the single equatorial plate of prophase stage is split into two daughter equatorial plates and the stage of metaphase ends.*

Anaphase. During this phase the chromosomes of each daughter equatorial plate move towards the corresponding centrosome along the fibrils of the achromatic spindle. As the chromosomes come closer to the centrosome the cell body shows signs of constriction which is disposed circularly around the equator of the achromatic spindle. *With the appearance of the constriction around the cell the anaphase stage ends.*

Telophase. This is the terminal phase of the mitotic cell division in which the circular constriction around the cell body which appeared during anaphase, gradually deepens until the cell is completely divided. With the gradual deepening of the constriction in each half of the cell the arrangement of the chromatins is reversed; that is, at first the chromatin skein is reformed, then the network of chromatins and finally the nucleoli and the nuclear membrane re-appear.

Heterotypical and Homotypical Mitosis. The heterotypical and homotypical mitosis are special types of cell division associated with the maturation division of the germ cells.

Heterotypical Mitosis. The primitive germ cells which are lodged in the sex glands of either sexes pass through three stages during their life cycle—*stage of multiplication, stage of growth* and *stage of maturation division.* During the stage of multiplication they multiply by the usual process of mitotic cell division; during the

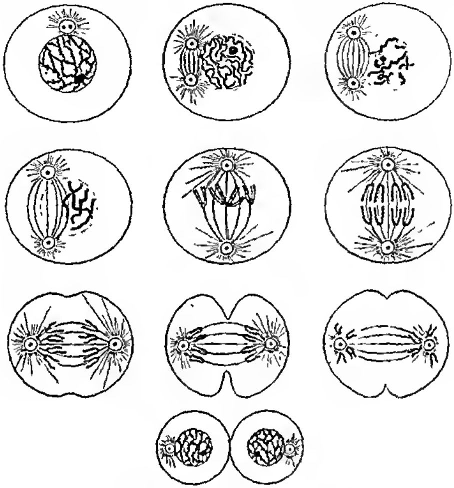


Fig. 13. Mitotic cell division.

stage of growth no further division takes place but the individual germ cell grows up to considerable maturity when they are in a position to attain their full maturity by dividing twice only to reproduce 4 cells and this final division is known as the *maturation division.* The first maturation division is the heterotypical mitosis or meiosis, a reduction division in which the number of chromosomes is reduced to half in each of two daughter cells resulting out of the division of the cell. In usual mitotic division each of the chromosome splits up into two by which the total number of chromosomes is doubled up, that is, if the mother cell contains 48 chromosomes, by splitting they become 96 and half the number of these chromosomes(48) passes to each of the two daughter cells, therefore the daughter cells having the same number of chromosomes with their mother cell. In heterotypical mitosis the chromosomes do not split and instead half the number of the total chromosomes passes to the daughter cell straightway, that is, if the mother cell contains 48 chromosomes 24 of them pass to each of the daughter cells, thus the number of chromosomes is reduced from 48 in the mother cell to 24 in the daughter cell—hence called the reduction division.

Homotypical mitosis. The homotypical mitosis occurs during the second maturation division of the germ cells. In this the chromosomes divide as in usual mitosis and the daughter cells have the same number of chromosomes with their

mother cell. It differs from usual mitosis in that here the mother cell starts its reproduction with the reduced number of chromosomes (24) in comparison with the somatic mother cell which contains 48 chromosomes. Moreover, the resulting daughter cells in homotypical mitosis of female germ cells are of unequal size—one large and one small. In usual mitosis the resulting daughter cells are of equal size and are usually smaller than the mother cell. The achromatic spindle rotate transversely with one of its pole forming a protrution of the cell wall and afterward a constriction soon appears around the protrution which cuts off the portion of the cytoplasm together with the chromosomes and thus one of the daughter cells become smaller and the other larger. In the usual mitosis the daughter chromosome occupy the poles of the achromatic spindle which extends from one end of the cell to the other and as the cleavage passes through the equator of the achromatic spindle the resulting daughter cells are of equal size. The daughter cells of the maturation division of the male germ cell are of equal size.

AN INTRODUCTION TO THE TISSUES OF THE BODY

It is interesting to note how from a fertilised ovum, a minute structure, a fully grown foetus is developed through process of cell division and cell differentiation. The un-differentiated cell mass of early embryonic life, at certain stage of development, differentiates into three embryonic layers, the ectoderm, entoderm and mesoderm, by a hitherto unknown process of physico-chemical changes. It is from these three embryonic layers, by an intricate process of growth and differentiation, all the tissues of the body are developed, and they become so harmonised as to form different functional units which are inter-related and inter-dependent on one another in the performance of an individual function. Thus a muscle, which is composed predominently of muscle fibres, is an integrated functional unit which contains not only muscle fibres but also blood vessels, nerves and fibrous tissue, all of which are harmonised during muscular action.

Thus a tissue may be defined as an assemblage of cells (with their processes) having similar structure and function which are held together by intercellular substances, and are arranged in distinctive forms having contained within them other co-ordinating tissue elements.

If we look into the structural integrity of our body we can see that as a tissue is made up of cells, so our body is an assemblage of tissues, different from one another both in structure and function. The following are the elementary tissues of which the human body is made up:

(1) *Epithelial tissue.*
(2) *Connective tissue.*
(3) *Sclerous tissue.*
(4) *Blood*
(5) *Lymph*—has been described along with lymphatic vessels.
(6) *Muscular tissue.*
(7) *Nervous tissue.*

Before going into details of the elementary tissues it is necessary that the student should know about the histological techniques, by which a tissue is prepared for necessary examinations. Therefore in the following few pages some of the common histological techniques have been described in brief.

HISTOLOGICAL TECHNIQUES

When time is a factor and decision as to the identity of cells and intercellular structures is to be taken quickly, as for example, while operating on a patient the surgeon wants to know about the histological diagnosis of a particular tissue in order to decide his line of action, some quicker methods of histological techniques are followed. But, by these methods, the preparation cannot be preserved (without subsequent fixing) for recording purposes as the tissue deteriorates after sometime. For recording purposes a tissue is subjected to elaborate processes of preperations

before it is ready for microscopical examination and permanent preservation. Thus a histological preparation may be made either temporarily or permanently.

TEMPORARY PREPARATIONS

(1) **When the material is a liquid.** A drop of the material which may be either blood, pus, cerebrospinal fluid or any other body fluid is put on a slide and is examined under a microscope. Alternatively, a smear is made on a glass slide, fixed by passing the slide quickly over the flame of a burner, stained and examined under a microscope. If the drop or the smear is found to contain too many cells, which overlap one another thereby obscuring proper identification, dilute the fluid with normal saline and then examine as above. If the cells in the drop or in the smear are found to be too scanty the fluid should be centrifuged and the sediment should be examined as above.

(2) **When the material is a solid.** A solid material may be prepared for histological examination by any of the following methods:

(a) *Scraping.* The solid mass is subjected to scraping with a glass slide or with a cover slip and the scraped out material is spread on a glass slide as a smear, fixed by passing the slide over the flame of a burner, and is examined as such or after staining. The scraped-out material may also be mixed with normal saline and a drop preparation may be made for examination.

(b) *Teasing.* In this method the tissue is disturbed by means of mounted needles under normal saline solution and then is spread on a slide, fixed over the flame and examined.

(c) *Maceration.* The process of dissociation by chemical agents is called "maceration". The chemicals commonly used for this purpose are alcohol 33%, formalin 1 in 500 aquaous solution, and nitric acid 1 in 4 dilution with glycerin-water mixture (equal parts of glycerin and water). The tissue has to be kept in any of the above solution for a day. 35% pottassium hydroxide solution takes about ½ an hour to macerate a tissue and is a quicker macerating fluid.

(d) *Sections.* The material is cut into thin sections either by hand with a knife, or by a freezing microtome after the material has been treated in gum solution. The thin section is then examined under a microscope with or without staining.

PERMANENT PREPARATION. Tissues other than bones, teeth and those containing calcareous deposits, which need to be passed through a process of decalcification are, first of all, fixed in some *fixative solution* in fresh condition and then they are prepared for embedding and cutting into thin sections. In preparing tissues for histological section a small piece having 2 mm. thickness is suitable.

Fixative solution. Before a tissue is prepared for embedding, it is "fixed" by keeping it in some chemical solutions for some time (time varies according to the nature of the tissue) which may be *solutions of mineral or organic acids* such as hydrochloric acid, chromic acid, picric, osmic or acetic acids, *solutions of salts of heavy metals* such as mercuric chloride, potassium bichromate etc., *alcohol*, *neutral formalin* or *combination of any of the above solutions.*

By fixation the relation of the cells and inter-cellular structures are least disturbed, in other words, they are "fixed" in their position. It renders the tissue more resistant to any subsequent treatment and the hardness imparted to the tissue by the fixatives is the first step towards preparing it for section cutting.

It is known by experience that some of the fixatives, such as formalin, shrink the tissues, while acetic acid swell them. Thus, in search of an ideal fixative, and to obviate these difficulties, out of continuous researches, the following fixatives, in which a judicious combination of different fixatives has been made, have been found to be suitable.

2

(1) *Bouins fluid:*

Saturated picric acid solution ..	.. 75 c.c.
Formalin (10% Formaldehyde)	.. 25 c.c.
Glacial acetic acid ..	.. 5 c.c.

Time of fixation—18-24 hours.

This fixative is unsuitable for kidney and tissues containing mucin.

(2) *Susa:*

Saturated solution of mercuric chloride	.. 50 c.c.
Formalin ..	.. 20 c.c.
Glacial acetic acid	.. 1 c.c.
Trichlor acetic acid ..	.. 2 grams.
Distilled water ..	.. 30 c.c.

Time—3-12 hours

(3) *Zenker's Fluid*

(a) *Stock solution*

Mercuric chloride ..	.. 5 grams.
Potassium dichromate ..	.. 2·5 "
Sodium Sulphate ..	. 1·0 "
Distilled water ..	.. 100 c.c.
(b) Glacial Acetic Acid	.. 5 c.c.

(to be added to the above stock solution just before use)

Time—3-24 hours.

(4) *Muller's Fluid:*

Potassium bichromate ..	.. 2·5 grams.
Sodium Sulphate	.. 1·0 "
Distilled water	.. 100 c.c.

Time 15 days.

The above fixative is suitable for nervous tissue.

Methods of embedding a tissue. A tissue may be embedded in gum or gelatine, paraffin wax and celloidin. The principle involved in all the above methods of embedding is the same. A small delicate tissue is difficult to be handled by itself and for better handling and to avoid distortion of the tissue during section cutting it is placed in a supporting medium which varies in its consistency at varying temperature, liquid at a higher temperature, and solid, but allows smooth cutting, at a lower temperature. The tissue is embedded in the liquid medium which is then allowed to solidify in a special container to form small blocks. Alternatively, a supporting medium may be formed around the tissue by freezing method. When such a block is subjected to a cutting instrument (Microtome), the tissue together with its supporting medium cuts as one mass which prevents distortion and helps in making thin section of desired thickness.

Every method of embedding has some advantages and disadvantages and therefore, a beginner should make himself familiar with only one method at first and should practise other methods at a later stage. I would recommend for the beginners to use "paraffin-wax" method of embedding and for this, only this method has been described. For other methods of embedding, a student should consult a text book of histology.

Paraffin-wax method of embedding. The following procedures are commonly used in the paraffin-wax method of embedding.

Fixation. Kill the animal, preferably by coal gas, or by chloroform and immediately inject 10% formol saline (for mammals, use 0·9% sodium chloride) through the heart.

Preserve the specimen in the same fluid (10% formol saline) for at least three days (72 hours).

After keeping the tissue in the preservative solution for three days, clean it and leave it under running tap water for 12 hours.

Next wash the tissue with distilled water for half an hour.

Dehydration. Then dehydrate the tissue by keeping it in ascending grades of alcohol as follows:

(*a*) in 50% alcohol for 24 hours
(*b*) in 75% alcohol for 10-12 hours
(*c*) in 96% alcohol (rectified spirit) for 10-12 hours

Time to be adjusted according to the size & nature of the specimen

(*d*) In absolute alcohol for 12 hours. Time to be adjusted according to the size of the tissue.

Clearing & Embedding in Paraffin. Clean the tissue in cedar-wood oil (Xylol, Chloroform, oil of cloves or benzene may also be used for this purpose) with several changes until the specimen is either absolutely transparent or translucent.

Then keep the tissue in chloroform for 15 minutes to ½ an hour.

Then in chloroform and paraffin mixture 54°C (equal parts) for ½ to 1 hour.

In 54°C paraffin for ½ to 1 hour.

Then in 58°C paraffin for 2 hours.

Then in embedding paraffin 56°C or 60°C for 2 hours.

Embed in 60°C fresh paraffin.

The embedded tissue in block is then cut into section, each section having 10μ in thickness. Sections are to be taken on albuminised slide and to be dried inside the incubator for atleast 7-10 days. Then deparaffinise, stain and examine under a microscope.

Method of embedding an Embryo. An embryo may be embedded in paraffin-wax for necessary serial section or ordinary section in the following ways:

(1) Take out the embryo fresh from the uterus or egg and clear off the membrane carefully.
(2) Fix it in Bouins fluid for a few hours but never more than 17 hours.
(3) Treat it in distilled water for a minute or two and then dehydrate it by passing it through ascending grades of alcohol as follows:
  (*a*) Keep it in 50% alcohol from 14-16 hours.
  (*b*) In 75% alcohol for 6-8 hours.
  (*c*) In 96% alcohol for 6-8 hours (the yellow colour of the tissue should fade away almost completely).
  (*d*) In absolute alcohol from ½ to 6 hours depending on the size of the tissue.
(4) Then clear it by passing it through cedar-wood oil until it becomes transparent.
(5) Pass it through chloroform for 5 to 15 minutes.
(6) Then keep it in chloroform-paraffin (60°C) mixture for 15 minutes.
(7) In paraffin (54°C to 60°C) for 20-30 minutes.
(8) Embed in 60°C paraffin for 20-30 minutes.
(9) Finally embed in fresh paraffin 60°C.

Method of decalcification. Bones, teeth and structures containing calcarious deposits need to be decalcified after fixing the tissue in the usual way. After decalcification the tissue has to be passed through the same processes as is required for paraffin-wax embedding for other tissues. A small piece of the tissue is to be selected and to be kept in excess of any of the following decalcifying fluids until fully decalcified. The solution needs to be changed frequently.

Decalcifying fluids:

(1) Nitric acid solution, 3 to 5 per cent.
(2) Hydrochloric and Formic acid mixture.
(3) Sulphurous acid—tap water saturated with SO_2.
(4) Trichloracetic mixture.

Test for decalcification:

(1) X-ray test—examination by X-rays.

(2) Needle test—when properly decalcified the tissue could be punctured smoothly with a needle without any stony resistance.

After the bone has been fully decalcified it should be kept under running tap water for about 12 hours.

Staining of paraffin-wax sections. Depending on the nature of examination to be required a paraffin-wax section may be stained with *general stains* or with *special stains*. With general stains the nucleus and the cytoplasm of a cell are clearly defined and a tissue can be identified without much difficulty but identification of other intra-cellular structures and differentiation of all the finer details in a composite tissue are not possible

The following are the *general stains* commonly used:

(1) Haematoxylin and Eosin
(2) Iron Haematoxylin and Van Geison stain.
(3) Haematoxylin and Biebrich scarlet.
(4) Picrocarmine

Special stains. In order to study individual structure in a composite tissue, as for example, presence of nerve cells, nerve fibres, nerve endings, elastic fibres, fat cells etc, in a muscle or some other structure, special stains, which have special affinities for the same structure, are used The following are the special stains used for individual tissues.

(A) *Elastic fibres*:
(i) Weigerts resorcin-fuchsin stain.
(ii) Acid fuchsin
(iii) Orcein.

(B) *Inter-cellular substance*:
(i) Silver nitrate.

(C) *Fat*:
(i) Flemming's fluid.
(ii) Sudan III
(iii) Scharlack R.

(D) *Nerve Cells*:
(i) Golgis Silver method.
(ii) Cajals modification of Golgis Silver method.

(E) *Myelinate fibres*—Weigget-Pal method, Osmic acid method

(F) *Amyelinate fibres*—Ranson's method.

(G) *Degenerated Nerve fibre*—Marchi's staining.

The details of the different stains and staining methods are out of the scope of this book and for this, a student should consult a text book on histology. However, given below are the details of staining by "Haematoxylin and Eosin", the commonest general stain used in histology.

Haematoxylin and Eosin method of staining

(1) Deparaffinise the tissue by emerging the slide containing the tissue in xylol for 2 minutes (do not use xylol used in deparaffinising the tissue for any other purpose).

(2) Wash off the excess of xylol in absolute alcohol (do not allow the xylol to dry up on the tissue) for about half a minute (pour alcohol drop by drop).

(3) Dip in the slide with the tissue in 95% alcohol for half a minute, and then 75% alcohol, 50% alcohol and in distilled water for the same length of time (half a minute).

(4) Then stain the tissue with Erlick's Haematoxylin (matures after keeping for atleast 6 months, for methods of quick maturation, consult books on staining) for 7-10 minutes.

(5) Differentiate by adding 0 5% Hcl. Sol. in distilled water and to start with, wait for half a minute and then adjust the time as required. The cell outline, intercellular space and structures should be clearly outlined and this has to be judged by frequently examining the tissue while differentiating with Hcl. solution under a low power microscope.

(6) Wash thoroughly under a running tap water for atleast 20-30 minutes.

(7) Then pass the tissue through ascending grades of alcohol 50%, 75%, 95% keeping in each solution for half a minute.

(8) Then counter stain with saturated alcoholic solution of Eosin for about

half a minute—may be a little more or less according to the type of the tissue, bones take less time.

(9) Wash and differentiate in 96% alcohol (rectified spirit). Differentiation is to be judged as above by looking through the microscope.

(10) Dehydrate completely in absolute alcohol with two changes, first, for one minute, and the second, for two minutes.

(11) Wipe out the excess of alcohol with a linen and put the slide with the tissue into clear fresh xylol for two minutes.

(12) Take out the slide, dry it up with linen but never allow the tissue to dry up and then put one or two drops of canada balsam and mount with a cover slip. The tissue is now ready for examination.

Other Histological Methods

(1) *Intravital staining* or *Vital staining*. Some dyestuffs such as methelene blue, neutral red, trypan blue etc., are injected intravenously to a living animal and when the animal is killed subsequently some of the cells are found to take up the stain electively. Study of tissues by this method of staining is known as intravital staining. The following dyestuffs are found to have affinities for the cells or tissues noted against their names.

(*a*) Methelene blue—for nerve endings and nerve fibres.
(*b*) Janus green—for mitochondria.
(*c*) Trypan blue, lithium carmine, pyrrhol blue—for cells of reticulo-endothelial system.
(*d*) Neutral red—for vacuoles in the cytoplasm.

(2) *Supravital staining*. Some dyestuffs such as brilliant cresyl or janus green B etc., when added to the solution containing surviving tissues or cells, some of the cells show affinities for such stains as for example, reticulocytes for brilliant cresyl blue.

(3) *Hanging drop preparation*. By this method movements of some living cells can be seen through the microscope on a warm stage.

(4) *Micro-dissection*. Dissection of individual cell with fine glass needles under the guidance of a high power microscope is a method in histology usually known as micro-dissection.

(5) *Micro-incineration*. This is a method in which microscopic sections are incenerated and the ash left behind is examined for cellular inorganic constituent.

(6) *Ultra-centrifuge*. By this, contents of an individual cell can be split into different layers according to their specific gravity.

(7) *Tissue culture*. Living tissues isolated from their parent bodies can be made to grow in some suitable media and can be studied under a microscope.

(8) *Freezing-drying method of tissue fixation*. Where immediate histological diagnosis is a necessity, as during operation, a tissue may be frozen rapidly and then dehydrated in a vacuum and a section may be done immediately for necessary microscopical examination.

THE EPITHELIAL TISSUE

The epithelial tissue invests all free surfaces either externally or internally and makes them smooth and regular. Thus it is found externally over the free surfaces of the skin as epidermis, and as a generalised investment for all mucous membranes internally. At some situations such as in the anterior lobe of the pituitary gland, the liver lobule, and in the interstitial cells of the ovary, the epithelial cells instead of forming a surface investment are found as solid cords of cells.

Characters of epithelial tissue. Marked cellular preponderance, scanty intercellular substances, arrangement of the cells either in single or in multiple layers and the presence of the basement membrane, are the characteristics of the epithelial tissue.

The epithelial cells. The cells form the most conspicuous feature and are closely packed together. They may be either columnar, cubical or polygonal in shape and are arranged either in single or in multiple layers.

The inter-cellular substance. The inter-cellular substance is exceedingly scanty, so much so, that the cells appear to be continuous with one another, although the presence of the inter-cellular substance between the cells, which resembles like the connective tissue, can be shown by treating it with silver nitrate solution (shows reducing properties).

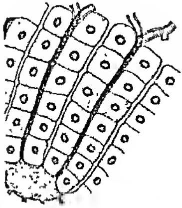


Fig. 20 Structure of a Liver lobule

Note that the epithelial cells are arranged in column so as to form cords of cells.

Fig. 21. Structure of œsophagus. (Microphotograph)

Note that the epithelial cells on the top form a generalised surface investment.

N.B.: In some situations such as in the alimentary canal and in the "prickle-cell" layer of the skin (the existence of the inter-cellular substance is doubtful) cohesion between the cells may be seen to occur by protoplasmic bridges. In situations where growth activity is a dominant feature such as in the chorionic villi, and in the decidua of early pregnancy, demarcation between the cells cannot be made out and the whole field appears to be a protoplasmic mass or a syncytium.

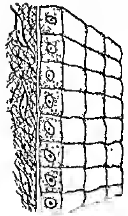


Fig. 22A. Cubical Epithelium.

Note that the cells form the dominant feature with minimum of inter-cellular substance. Note the difference between it and the connective tissue on the right side.

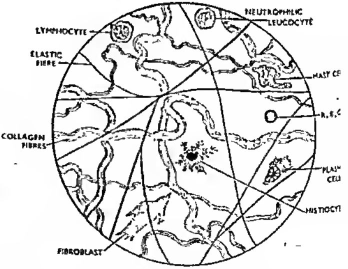


Fig. 22B Structure of loose connective tissue.

Note that the cells are scanty and wide apart in connective tissue.

Basement membrane. It is a condensed connective tissue membrane which make the base (hence basement membrane) for the epithelial cells and intervenes between

the latter and the sub-epithelial loose connective tissue. Presence of the basement membrane is one of the important characteristics of the epithelial tissue. In the thyroid gland, urinary tract, liver lobule and in some portions of the membranous labyrinth of the internal ear, the basement membrane is absent (exceptions).

Classification of epithelial tissue. The epithelial tissue, the cells of which are arranged in single layer, is called *simple epithelium* and where the cells are arranged in multiple layers it is called *compound epithelium*. Depending on the nature of the cells the simple epithelium is further subdivided into *columnar, pavement, cubical* and *columnar ciliated types*. Similarly the compound epithelium is subdivided into *transitional, stratified squamous cornified* and *stratified squamous non-cornified types*.

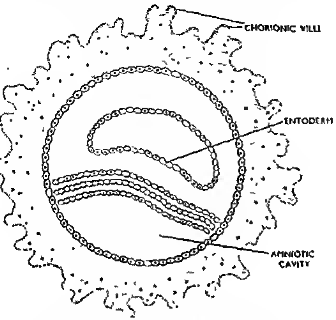
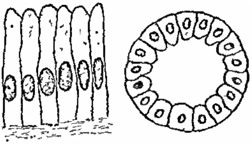


Fig. 23. Early human development with formation of trophoblast with chorionic villi.
Note that the epithelial cells of the chorion form a protoplasmic mass without any cellular demarcation.

In some situations the cells of the simple columnar epithelium are so much closely packed together that only the tallest ones appear on the surface while the others occupy a plane at some depth from the surface and thus they resemble like compound epithelium and hence they are called *pseudo-stratified columnar epithelium*.

In some places, particularly in the gastro-intestinal tract, the cells of the simple epithelium are arranged in typical formation whose main function is secretory and they are often classed as *glandular epithelium*. As they form a distinct group functionally, the secreting glands and glandular epithelium have been dealt with separately.



Columnar Epithelium.

Columnar epithelium in glandular formation.

Fig. 24. Columnar epithelium and section of a simple tubular gland.

Functionally the epithelial tissue subserves various functions in our body mechanics. Some of them are *protective* in nature, some are *secretory*, some are *concerned in diffusion of gasses and liquids* while some others are associated with the sensory nerves in special formation so as to subserve *sensory functions*.

Developmentally the epithelial tissue is found to arise from all the primitive germinal layers namely, ectoderm, entoderm, and mesoderm. Given below is the summary of classification of epithelial tissue:

1. **According to structure:**
   (A) *Simple epithelium* (consisting of single layer of cells):
      (*i*) Columnar — Pseudo-stratified columnar, Glandular.
      (*ii*) Cubical.
      (*iii*) Pavement.
      (*iv*) Columnar ciliated.

(B) *Compound epithelium* (consisting of several layers of cells).
- (i) Transitional.
- (ii) Stratified squamous cornified.
- (iii) Stratified squamous non-cornified.

2. According to function:

(A) *Absorptive and diffusive:*
- (i) Columnar.
- (ii) Pavement.

(B) *Secretory:*
- (i) Glandular.
- (ii) Cubical.

(C) *Protective:*
- (i) Transitional.
- (ii) Stratified squamous.
- (iii) Columnar ciliated.

(D) *Sensory:*
- (i) Epithelium associated with sensory end-organs.

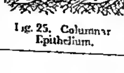
3. According to development:

(A) *Ectodermal:*
- (i) Epithelium of the skin and its appendages.
- (ii) Epithelium of the buccal cavity.
- (iii) Epithelium of the lower part of anal canal.
- (iv) Epithelium of the sensory end-organs.
- (v) Epithelium of the labyrinth of the internal ear and eye.

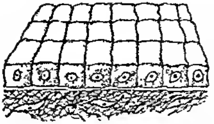
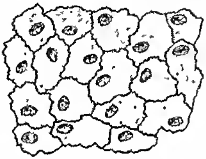
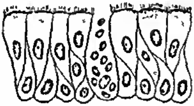
(B) *Entodermal:*
- (i) Epithelium of the digestive tract together with the glands with the exception of the buccal cavity and the lower part of the anal canal.
- (ii) Epithelium of the biliary passages.
- (iii) Epithelium of the respiratory system.
- (iv) Epithelium of the pharyngo-tympanic tube and the middle ear.

(C) *Mesodermal:*
- (i) Epithelium of the urinary and genital systems.

CHARACTER AND DISTRIBUTION OF SIMPLE EPITHELIUM

Varieties	Character	Distribution
Columnar	Cells are tall and are arranged in columns. In cross section they present a mosaic appearance of hexagonal figures closely packed together. The nucleus is found to be situated nearer the base of the cell. Cells rest on basement membrane which separates them from the sub-epithelial connective tissue. Seen in profile the cells present a striated edge towards the surface in some places.  Fig. 25. Columnar Epithelium.	Mucous membrane of the gastro-intestinal tract from stomach to the upper part of the anal canal. Mucous membrane of the gall bladder and the biliary passages. Mucous membrane of the excretory ducts of many glands.

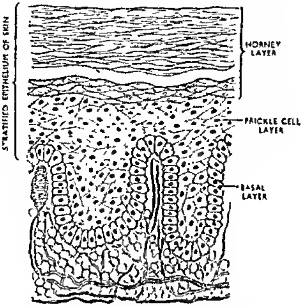
CHARACTER AND DISTRIBUTION OF SIMPLE EPITHELIUM—*Contd.*

Varieties	Character	Distribution
Cubical	Cells are smaller (length and breadth almost equal) than the *above; the nucleus* occupies the centre of each cell; the protoplasm is granular.  Fig. 26. Cubical Epithelium.	Secretory alveoli and ducts of many excretory glands. Follicles of the thyroid gland. Germinal epithelial layer of the ovary. Choroid plexus.
Pavement	Scale-like cells of varying shape. They are flattened and are closely fitted together to present a mosaic appearance. The nucleus is central in position and presents a superficial bulging due to thinness of the cells.  Fig. 27. Pavement Epithelium.	Alveoli of the lungs. Chorionic villi of placenta. Rete testis. Bowman's capsule and descending limb of Henley's loop of renal unit. Excretory ducts of pancreas and smaller glands. Internal surface of tympanic membrane.
Columnar ciliated	These are columnar cells with hair-like processes which project from the free surface of the cells. Just within the cell-outline opposite the free surface each ciliary process is found to present a knob-like thickening known as the *basal knob of Engelmann.* From these knobs the processes penetrate through the cell substance and converge to a point close to the fixed end. The basal knobs are believed to represent the fragmented centriole of the cell.  Fig. 28. Columnar ciliated Epithelium.	Respiratory tract from nose to the *terminal bronchiole* except the vocal cord which is lined by stratified epithelium. Paranasal sinuses. Nasal part of pharynx. Uterine tube. Endometrium of the uterus. Pharyngo-tympanic tube and the tympanic cavity. Ependyma of the ventricles of the brain and the central canal of the spinal cord. From efferent ductule of the testis up to some portion of the epididymis (?).

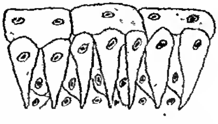
CHARACTER AND DISTRIBUTION OF COMPOUND EPITHELIUM

Types	Character	Distribution
Stratified squamous cornified	The cells are arranged in several layers and they become gradually flattened as they approach the surface (squamous character). The cells of the surface layer gradually lose their protoplasmic character and become compressed to lose their cellular outline and they are converted into a horny material known as the keratin.	Epidermis of skin.

CHARACTER AND DISTRIBUTION OF COMPOUND EPITHELIUM—*Contd.*

Type	Character	Distribution
Stratified squamous cornified —*Contd*	 Fig. 29. Section of skin showing stratified squamous cornified type of epithelium.	
Stratified squamous non-cornified	Histologically the structure is the same as stratified squamous cornified type except that the surface layer of cells is not keratinised.  Fig. 30. A section of Oesophagus (Microphotograph). Note above that the epithelium does not show the presence of horny layer.	Buccal cavity, tongue, lower part of pharynx, oesophagus, lower part of anal canal, cornea, vocal cord and vagina.

CHARACTER AND DISTRIBUTION OF COMPOUND EPITHELIUM—*Contd.*

Types	Character	Distribution
Transitional	It is a variety of compound epithelium and *consists of only three or four layers of cells.* Cells of all the layers are protoplasmic and *they fail to show "squamous character"* that is, the character of gradual flattening as the cells approach towards the free surface. However, the surface layer of cells is slightly flattened and they present a depression underneath which fits with the globular bulging of the pearshaped cells of the layer underneath (second layer). The tapering ends of these cells touch the basement membrane and in between the tapering ends of the two adjacent cells one or two layers of smaller polyhedral cells intervene which form the third or fourth layer of cells as the case may be  Fig. 31. Transitional epithelium	Renal pelvis, ureter, urinary bladder, and most of the urethra.

THE GLANDULAR EPITHELIUM AND THE SECRETING GLANDS

Glandular organisation. Some of the epithelial cells are seen to possess secretory qualities such as the goblet cells of the intestinal tract which secrete mucin into the intestinal canal. The goblet cells are ordinary columnar cells in which the secretory granules (Mucin) are formed; these granules gradually accumulate towards the free surface of the cell and distend it enormously and ultimately the superficial portion of the cell ruptures giving out its content into the intestinal lumen; the cell concerned subsequently regains back its original form by reparative processes. This is the simplest form of glandular organisation in which a single cell acts as a secreting gland and may be called a *unicellular gland.* In further elaboration of the glandular mechanism some of the secretory cells are found to be grouped together at places within the lining epithelium, particularly in the buccal cavity, so as to form *multicellular glands.* Still further in the mechanism are found the more specialised organisations in which groups of cells from the lining epithelium evaginate out, are variously arranged and remain connected with the original site by a narrow tubular passage, the duct of the gland. The more intricate mechanism is associated with the elaboration of the ductless glands. During early developmental period many of them originate in the same way as the glands with duct but sometime during the developmental phase they become disconnected from their source of origin, lose their duct, so become ductless, and become entangled in situations remote from their primary source of origin. Other types of ductless glands are found to be developed in more ingenious ways.

Thus it appears that some of the epithelial tissues acquire specialisation with either secretory or excretory qualities and are variously organised to form different glandular types and the epithelium of which it is made up is columnar or modified columnar types and is usually called the *glandular epithelium.* Therefore *glands* may be defined as organised bodies (made up of glandular epithelium), which may be likened to the chemical laboratories in different instalations for different products, producing chemical substances which are either utilised in the body as secretions or they are thrown out of the body as waste products in the form of excretions.

Classification of glands. Glands may be classified variously according their structure, mode of distribution of their secretion, behavior of the gland during secretion, and according to their development as follows:

(A) **According to structure.** As mentioned previously secreting cells of the glands may be arranged variously so as to form a definite glandular pattern. Structurally the following glandular types may be recognised:

(i) *Simple tubular gland.* From the free surface the secreting cells evaginate out in the form of a tube, as for instance, the intestinal glands.

(ii) *Branched tubular.* Here from the original tubular outgrowth diverticula spread out in different directions so as to give a branched appearance. Thus different tubular glands open to the free surface by a common passage known as the duct of the gland which is lined by non-secretory epithelium. The pyloric glands of the stomach, the lacrimal gland etc., fall under this sub-group.

(iii) *Coiled tubular.* The sweat gland of the skin falls under this sub-group. Here the original tubular diverticulum elongates considerably and at its blind end it is coiled up which is the actual secreting part of the gland. The long tubular connection to the skin surface constitutes the duct.

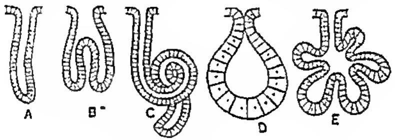


Fig. 32. Different types of simple glands.

A—Simple tubular gland.
B—Branched tubular gland.
C—Coiled tubular gland.
D—Simple alveolar gland.
E—Simple branched alveolar gland.

(iv) *Simple saccular.* Here the secretory part of the gland presents a sac-like dilatation known as *acinus* or *alveolus.* Any dilatation at the end of a narrow passage is usually known as *acinus* or *alveolus.* This type of gland is found in the frog's skin. They are not present in the mammals.

(v) *Simple branched saccular.* In this type of glands two or more saccular dilatations are connected to the free surface by a common narrow passage, the duct of the gland. Sebaceous and tarsal glands fall under this sub-group.

(vi) *Compound tubular gland.* This is a further elaboration of the branched simple tubular gland where each tubular branch spreads out in numerous tubular diverticula. Thus each secreting portion joins its parent stem with its small non-secretory passage, the *ductule.* Several

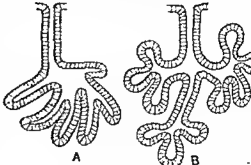


Fig. 33. Different types of compound glands.

A—Compound tubular gland.
B—Compound alveolar gland.

ductules join to form a *duct* and several ducts open into the main stem, the *main* or the *collecting duct* which carries the secretions to the free surface.

(vii) *Compound saccular or alveolar gland.* This resembles the compound tubular glands except that the secreting part of the glands presents saccular dilatations. The glandular pattern resembles like the bunches of grapes and hence this type of gland is also known as compound racemose gland (Racemes=bunches). Pancreas, salivary glands and sebaceous glands fall under this group.

(viii) *Compound tubulo-saccular or tubulo-racemose gland.* As the name implies this is a combination of both types of compound glands. Glands of the respiratory passages and parts of salivary glands are of this type.

(B) According to mode of distribution of the secretion

(i) *Exocrine glands.* The exocrine glands pour out their secretion on to the surface her directly or indirectly by means of ducts. The salivary glands, sweat glands, testinal glands etc. fall under this sub-group.

(ii) *Endocrine glands.* The endocrine or the ductless glands have no ducts and ey secrete chemical substances known as *hormones* which pass inwardly and are sorbed into the blood through which they are distributed throughout the body. yroid, pituitary, the interstitial cells of the ovary, suprarenal etc. are endocrine ands.

(iii) *Mixed types.* Glands having both internal and external secretions are of is type. Pancreas, testes and ovary are examples of mixed type of glands possessing oth type of secretions.

(C) According to changes in the gland cells during secretion

(i) *Epicrine glands.* In this type the cells of the glands are not destroyed. The cretory granules pass out of the cell body at its free surface, the cell membrane ting as a dialysing membrane.

(ii) *Apocrine glands or Merocrine glands.* In apocrine glands the secretory granules cumulate within the cell under pressure and appear towards the free surface and timately part of the cell bursts out to release its secretion; subsequently the cell is stored to its usual form by reparative processes. Goblet cells and some of the eat glands, mammary glands are of this type.

(iii) *Holocrine glands.* In this the secretory mechanism is almost the same as above at here the whole cell is destroyed during the discharge of the secretory granules. ebaceous glands fall under this sub-group.

(D) According to development. Developmentally glands may be classified ito *ectodermal, mesodermal* and *entodermal* glands. Mammary glands, sweat glands .c. are ectodermal in origin. Kidneys and portions of the testis and ovary are mesoermal in origin whereas the glands associated with the digestive and respiratory acts are entodermal in origin.

ENDOTHELIUM, MESOTHELIUM AND MESENCHYMAL EPITHELIUM

The linings of all the serous sacs, the chambers of the heart, blood vessels, ymphatics, the ventricles of the brain, the central canal of the spinal cord and the ub-arachnoid spaces have some common features with the epithelium when examined icroscopically and in fact, they are often indistinguishable from the epithelial issue; like epithelial tissue the cells of these linings are closely packed with the minimum of intercellular substance—the cells resembling pavement type. Developmentally all these cells are of mesodermal in origin and they are formed by lifferentiation of the mesenchymal tissue (primitive connective tissue) whereas the pithelial tissues arise independently from the ento-, ecto-, and mesoderm. Experimental studies show that in case of damage of these cells (cells lining serous sacs etc.) eparation takes place either by mitosis of adjoining cells or by differentiation of the

underlying connective tissue and it has also been shown that these cells under some conditions may be de-differentiated into connective tissue cells (fibroblast). Repair of the epithelial tissue takes place by mitotic cells division or by re-adjustment of the other lining cells but *the cells have no power to be changed into connective tissue.* Thus the cells forming the lining of the above mentioned places, in spite of close resemblance to the epithelial tissue, form a group by themselves, and are divided into *endothelium, mesothelium* and *mesenchymal epithelium.* The *endothelium* forms lining of the chambers of the heart, blood vessels and the lymphatics, the *mesothelium* forming the lining of all the serous sacs whereas the *mesenchymal epithelium* forms the lining of the ventricles of the brain, sub-arachnoid, and sub-dural spaces, central canal of the spinal cord, the perilymphatic spaces of the internal ear and the different chambers of the eyeball. The mesothelial cells lining the serous sacs are also called *serosal cells* and similarly the mesenchymal cells lining the ventricles of the brain and the central canal of the spinal cord are also called *ependymal cells.* The following is a chart showing differences between these cells (endothelium, mesothelium and mesenchymal epithelium) and the epithelium:

	Endothelium Mesothelium Mesenchymal Epithelium	Epithelium
Origin.	Mesodermal in origin.	May be of ecto-, endo-, or of mesodermal origin.
Repair.	Repair takes place either by mitotic cell division of the adjacent cells or by differentiation of the underlying connective tissue cells	Repair takes place either by re-adjustment of the adjoining cells or by mitotic cell division of the adjoining cells. The underlying connective tissue cells are not transformed into epithelial cells.
Power of de-differentiation.	These cells may be de-differentiated into connective tissue cells, that is, fibroblasts, under some conditions.	Epithelial cells have no power to be de-differentiated into connective tissue cells.

THE CONNECTIVE TISSUE

The connective tissue is the most widely distributed tissue in our body and is mesodermal in origin except the neurilemma sheath of nerves and some of the neuroglia (astrocytes, ependyma and oligodendroglia) cells of the C.N.S. It is called "connective tissue" because it forms the basis of connection between cells, and tissues, although in some situations, as for example, the capsule of many glands, it forms a "disconnecting" barrier between one type of tissue and the other. The capsule of a gland isolates it from the surrounding structures and thus allows the gland to work in isolation without any surrounding disturbance.

The characteristic features of the connective tissue. The most distinguishing feature of the connective tissue is *its intercellular substance which is highly developed and is found in abundance in contrast to scanty and sparse cells.* As the inter-cellular substance forms the main bulk, the cells are either obscured or they are scattered wide apart from one another. Both the cells and the inter-cellular substances are varying and the type of the connective tissue mostly depends on the nature of its inter-cellular substance.

THE CONNECTIVE TISSUE CELLS. The cells found in the connective tissue can be ouped under two heads, local or histogenous cell, migrated or haematogenous lls.

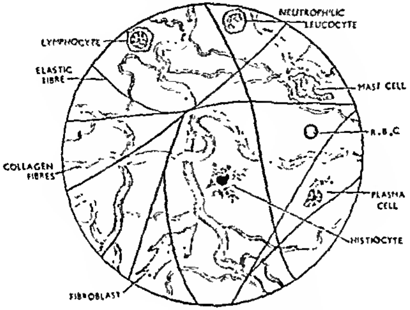


Fig. 31. Structure of loose connective tissue.

(A) **Local or Histogenous cells:**

(*i*) Fibroblasts.
(*ii*) Histiocytes.
(*iii*) Fat cells.
(*iv*) Plasma cells.
(*v*) Mast cells.
(*vi*) Pigment cells.
(*vii*) Mesenchyme cells.

(i) *Fibroblasts.* Microscopically a fibroblast is seen to be roughly *triangular in hape with pointed processes.* Its cell outline is indistinct and the cell is often found to e embedded in a matrix of collagenous fibres and ence the name "fibroblast". Its *nucleus* is comparatively large and is oval in outline. The *cytoplasm* s usually clear and except a few fat globules no other ntracellular inclusions are found.

Product of the cell activity. Close association of the fibroblast with collagenous fibres has led to the conclusion that these collagenous fibres are the product of the cell activity. By recent experiments it has been proved that pseudopodial protrusion of the cell cytoplasm, which becomes detatched from the cell body, gives rise to the formation of these collagen fibres. It has also been proved that the production of collagen fibres by a fibroblast is dependent on two factors, one is the local factor of tension and the other is the presence of vitamin C. It is known that in scurvy, a vitamin C deficiency disease, wounds either do not heal at all or heal very slowly depending on the degree of vitamin C deficiency.

Fig. 33. Fibroblast.

(ii) *Histiocytes.* The term "histiocytes" means "tissue cells" and they for[m] irregular type of connective tissue cells which are truly phagocytic (engulf fore[ign] bodies, cell debris etc.) and hence they are alternatively called macrophages. The[y] are also known as resting wandering cells, adventi[tial] cells and clasmatocytes. They are usually non-mot[ile] but are seen to acquire amoeboid movements und[er] certain stimulus (in inflammatory process) and hen[ce] they are also called resting wandering cells in contra[st to] freely moving macrophages believed to be derived fro[m] the circulation. (See also reticulo-endothelial system [or] macrophage system).

Fig 36 Diagram of Histiocyte

Microscopically its *cell outline* is seen to be irreg[ular] but distinct in contrast to the fibroblasts whose c[ell] outline is indistinct. Its cytoplasm is granular a[nd] may contain pigments and debris and vacuoles. I[ts] nucleus is kidney-shaped and stains darkly. It sho[ws] selective staining reaction to vital stains (stains, whic[h] when injected, are taken up by the cytoplasm of th[e] normal living cells and are called vital stains) by which [it] can be isolated from the rest of the connective tiss[ue] cells.

(iii) *Fat cells.* Have been dealt under adipose tiss[ue].

(iv) *Plasma cells.* These cells are sparingly distributed in the body and are generally found in the sub-peritoneal tissue of the omentum and in the submucous tissue of the intestine. They are believed to be the degenerative product of ordinary lymphocyte and are usually found to be associated with chronic inflammations such as tuberculosis.

Fig 37. Plasma cell.

Microscopically they are round cells *with round or oval eccentric nucleus, the chromatins of which are arranged radially so as to resemble a "cartwheel".* The cytoplasm is homogeneous and stains with basic dyes, particularly at its periphery. Its central zone opposite the nucleus is marked by a rounded clear area.

(v) *Mast cells.* They are usually found in close proximity to the blood vessels and are usually less numerous. They are believed to produce an anti-coagulant substance known as the *heparin.*

Microscopically they are seen as round or polygonal cells with granular cytoplasm which stains with basic dyes. The nucleus is round or oval and has no special distinctive feature.

Fig. 38. A Mast cell.

(vi) *Pigment Cells.* The name pigment cell is quite significant in that its cytoplasm contains a pigment known as *melanin.* They are mostly found in the pigmented areas of the body such as the gums, areola of the nipple, external genitalia, iris and the pigmented areas of the midbrain and the hindbrain. They are small branched cells with pigment in their cytoplasm.

(vii) *Mesenchyme Cells.* These are embryonic type of connective tissue cells which are also seen in fair numbers in the adult. They are, being embryonic type, capable of differentiating into any of the connective tissue cells depending on the local influence.

STRUCTURE. As already mentioned the areolar tissue is seen to consist of cells and fibres which are embedded in a homogeneous ground substance.

The cells are:

(1) Fibroblasts.
(2) Histiocytes.
(3) Fat cells.
(4) Plasma cells.
(5) Mast cells.
(6) Pigment cells.
(7) Mesenchyme cells.

The fibres are:

(1) white or collagenous fibres.
(2) yellow elastic fibres.

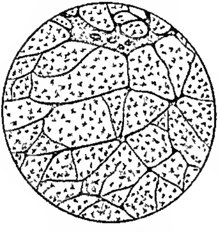


Fig. 41. White fibrous tissue as seen in a section of a tendon.

Dense connective tissue or Fibrous tissue. "Fibrous tissue" as the name implies is a variety of connective tissue which is composed mostly of fibres which may be either white collagenous fibres or yellow elastic fibres. Depending on the nature of the predominent fibres, the fibrous tissue may be divided into (*a*) white fibrous tissue and (*b*) yellow elastic tissue.

(*a*) WHITE FIBROUS TISSUE. Structurally the white fibrous tissue is made up almost entirely of collagen fibres with a few fibroblasts scattered amongst the fibres. *The fibres are arranged in bundles which run in one direction or the other.* The fibres are held together in bundle by areolar tissue which carries blood vessels, lymphatics and nerves. The individual bundle may branch but the *individual fibre never divides.*

Distribution. The white fibrous tissue is usually found in those places where great tensional force with resistance is required as in the following:

(1) Tendon and aponeurosis of muscles.
(2) Ligaments.
(3) Retention bands.
(4) Deep fascia.
(5) Perichondrium.
(6) Periosteum.
(7) Dura matter.
(8) Fibrocartilage.

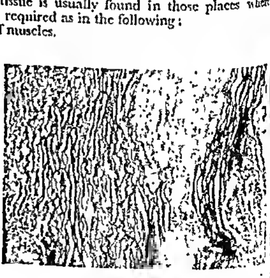


Fig 42. Elastic fibres of Human Aorta.
Microphotograph to show elastic fibres of Human Aorta after Weigerts stains for elastin.

(*b*) YELLOW ELASTIC TISSUE. Structurally the yellow elastic tissue is characterised by the presence of the elastic fibres in its matrix in abundance. The *fibres run singly, branch and anastomose freely.* By virtue of their elasticity they curl up when divided.

Distribution. It is found in those structures whose function is to subserve the property of "stretch and recoil", in other words, where "spring action" is necessary. It is found in the following:

(1) Ligamentum nuchae and flavum.
(2) Connective tissue framework of the lungs.
(3) Capsule of the spleen.
(4) Walls of blood vessels.
(5) Vocal cords.

DIFFERENCE BETWEEN WHITE FIBROUS AND YELLOW ELASTIC TISSUE

	White fibrous tissue	Yellow elastic tissue
:olour.	*Shining white in colour.*	*Yellowish in colour.*
ibres,	(*a*) Thicker in consistence. (*b*) Fibres usually run in wavy bundles. (*c*) Individual fibre never branches but the individual bundle may branch and anastomose each other. (*d*) When divided the fibres do not curl up due to absence of elasticity. (*e*) When transected the fibres present a flat surface.	(*a*) Thinner in consistence. (*b*) Fibres usually run singly but may form loose bundles in which the individual fibre can be identified. The bundles are usually straighter. (*c*) Individual fibre freely branches and anastomoses each other. (*d*) When divided the fibres curl up due to elastic recoil. (*e*) While transected the fibres are seen to be angular with angles rounded off.
:ature of distribution.	Distributed in those places where great tensional force with resistance is required.	Distributed in those places and organs which are to subserve the function of "stretch and recoil".
Reaction to heat and acid treatment.	Fibres contain an albuminoid substance known as collagen which yields gelatin on boiling and is easily digested by acid.	The fibres contain an albuminoid substance known as elastin which is resistant to both boiling and to acid treatment.
Reaction to peptic and tryptic digestion.	Resistant to tryptic digestion but can be digested by pepsin.	Resistant to peptic digestion but they can be digested by trypsin.
Selective staining reaction.	Can be selectively stained by Van Giesons stain in which they look bright red in colour.	Can be selectively stained by orcein in which they look reddish-brown in colour.

Adipose connective tissue. The adipose tissue is composed of fat cells which re arranged in the forms of lobes and lobules. Surrounding the lobes and lobules an envelope of areolar tissue which carries a network of blood vessels. They are ot uniformly distributed in the body but they show tendency to be accumulated nore in certain parts than the others. Thus in the subcutaneous tissue, particularly n the abdomen, the greater omentum, the mesenteries and in the renal fascia, he adipose tissue is found to be selectively deposited in abundance, and these places where fat accumulation is mostly marked, are called the *fat depots* of the body. In ases of starvation and malnutrition fat is withdrawn first from these fat depots and hen from the other tissues into the general circulation to meet the metabolic demands f the body. The process of withdrawal follows a definite course as it has been seen hat while the depot fat is completely depleted, the fats in the palm of the hand and he sole of the foot are almost unaffected. Thus withdrawal of fat seems to be elective in some way and the withdrawal does not affect those parts where fat has to ubserve the mechanical function of ***protecting pad*** such as the sole of the foot and he palm of the hand.

Distribution. The adipose tissue is widely distributed in all parts of the body except in the following places :(1) subcutaneous tissue of the penis, (2) labia minora (3) scrotum, (4) eyelids, (5) cranial cavity and (6) the lungs (except at the hilum).

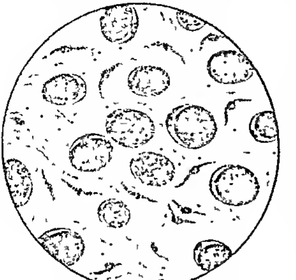


Fig. 43 Adipose connective tissue.

Mode of formation. The adipose tissue which is composed mainly of fat cells with minimum intercellular substance is derived from the undifferentiated mesenchymal cells both in the adult as well as in the foetus. Fat globules first appear as minute droplets in the cytoplasm of the cell and later on these droplets coalesce together to form a large globule which is surrounded by a thin layer of cytoplasm; with the enlarging fat globule the cytoplasm is compressed at the periphery and at the same time the nucleus is also displaced to one side of the periphery or the other and the cell looks either spherical or oval.

Structure. Thus a fat cell consists of a rounded cell containing a large globule of free fat which is surrounded by a thin layer of cytoplasm and a nucleus which is displaced at the periphery. The fat cells are stained black by osmic acid.

The intercellular substance is formed by areolar tissue.

Mucous connective tissue. This is a variety of connective tissue which is usually found in many parts of the body during development and in the jelly-like material of the umbilical cord (Wharton's Jelly). It is not present in the adult body. Structurally this type of connective tissue consists of star-shaped fibroblasts with anastomosing processes, mucin-containing soft ground substance and a few collagen fibres.

Reticular tissue. This variety of connective tissue is found to form network of fine connective tissue fibres known as reticular fibres which branch and anastomose freely. In the meshes of the networks of reticular fibres are the cells which vary according to the nature of the tissue in which the reticular fibres form the supporting networks.

Distribution. It is usually found as a supporting networks in the lymph node, bone marrow, splenic pulp and in the liver.

In a lymph node the cells in the meshes are the lymphocytes. In the bone marrow and the splenic pulp in addition to other cells, reticular cells, which anastomose each other to form a protoplasmic syncytium, are usually found.

They are thin branching fibres which resist peptic digestion and can be stained selectively with silver oxide and hence they are also known as *argyrophil fibres.*

Functions of the Connective tissue. The collagenous fibres of the connective tissue which come to the formation of ligament, tendon of muscles, retention bands, deep fascia etc., are very tough, rigid and inelastic. Metabolically they are less active and hence they are sparingly supplied with blood vessels and are less expensive (metabolically) in upkeep. By virtue of the above qualities they are specially adapted to withstand tensile forces. The elastic fibres dominate the field of those structures which are to work by "stretch and recoil" as for instance the lungs, blood vessels etc. The connective tissue cells also function in a variety of ways. However, given below is a summary of the functions of the connective tissue :

(A) **Mechanical functions.**

(1) It is a supporting tissue and forms the basis of support for the other tissues.

(2) It serves as a packing material to fill up the hollows and spaces around various organs and helps in anchoring them in position.

(3) The deep fascia of the connective tissue being inelastic and rigid helps circulation through veins and lymphatics mechanically by causing compression over them during muscular contraction.

(4) In the form of retention band, pully etc., it changes the pull of muscular action and thus helps in precision of muscular movement.

(5) Mechanically it protects the blood vessels, muscles and nerves in the form of sheaths around them.

(B) **Defensive function.** *The histiocytes* and *some other connective tissue* cells being phagocytes protect the body from infection and other deleterious effects.

(C) **Reparative and regenerative functions.** The fibroblasts of the connective tissue help in healing processes by laying down collagenous fibres which are subsequently converted into scar tissue.

The primitive mesenchymal cells of the connective tissue which form the stem cells for all the tissues of mesenchymal origin, under favourable conditions, may be differentiated into specialised tissue in case some of them are damaged.

SCLEROUS TISSUE

CARTILAGES

The cartilages come next in order after bones in hardness. It is a variety of hard connective tissue or sclerous tissue and forms an integral part of the skeletal frame-work of the body. It is hard and at the same time elastic and is lighter than the bone. In contradistinction to bones the cartilage in the adult is an avascular structure although in the foetus large cartilage masses show the presence of "cartilage canals" for blood vessels. It can be cut with a knife easily and the cut surface presents a solid homogeneous appearance.

Development. In the foetus the cartilages develop from the mesenchymal cells. The cells in a mesenchymal condensation differentiate in situ into cartilage cells under the influence of local organisers and subsequently matrix formation starts with its usual specialisation. In the adult new cartilages may develop from connective tissue cells under suitable conditions.

Structure. Histologically the cartilage consists of groups of rounded cartilage cells surrounded by capsules and large amount of inter-cellular ground substance or matrix. The matrix may be either clear and homogeneous or it may contain visible fibres which surround the cells with their capsules. Depending on the nature of the matrix and on the number of the cells, a cartilage is sub-divided into *hyaline*, *cellular*, and *fibro-cartilage*; and depending on the nature of the fibres the fibro-cartilage is further sub-divided into *white fibro-cartilage* and *elastic fibro-cartilage* or *elastic cartilage*. The cartilage that covers the articulating surfaces of bones of a synovial joint is known as *articular cartilage*. The articular cartilage is a variety of hyaline cartilage but as it bears some special features of its own it has been described separately in the chapter on articular system or Arthrology.

The intercellular ground substance or the matrix. The matrix immediately surrounding the cells or the group of cells is different from the rest and is more basophilic and constitutes the "capsule". Chemically it is composed of chondromucoid and chondroalbuminoid substances and on boiling the chondromucoid substance is converted into chondroitin sulphuric acid. The visible fibres present in the matrix in some cartilages may be either collagenous white fibres or yellow elastic fibres.

A group of cells surrounded by a common capsule constitutes a *chondrone* which is the mechanical unit in a cartilage. Thus a cartilage is made up of a group of

chondrones which together with the surrounding fibres is specially adapted to res pressure forces. The ensheathing perichondrium, where present, is mechanical adapted to resist tensile force. In an articular cartilage where the perichondrium absent fibre-arcades spread from one margin to the other beneath the articular surf. and function as the tension-resisting component in this type of cartilage. Th. functionally a cartilage is mechanically sound in resisting both tensile and press. forces.

Hyaline cartilage. Most of the bones in the foetus are preformed in hyal cartilage which is subsequently replaced by bones except the articular surfaces whi persist as such throughout life and is better known as articular cartilages. All hyaline cartilages, except the articular cartilages, are enveloped by a fibrous sheath known as *perichondrium.* Although the articular cartilage is a variety of hyaline cartilage it has some special features of its own for which the articular cartilage has been described under a separate heading in the chapter on arthrology.

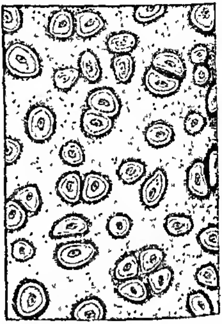


Fig. 44. Structure of Hyaline cartilage.

Structure. Histologically a hyaline cartilage consists of ensheathing perichondrium made up of fibrous tissue, encapsulated cartilage cells and homogeneous ground substance.

The cells. The cells are large, rounded and are surrounded by capsule. The nucleus is small with one or more nuclei; the cytoplasm is usually clear with a few fat droplets, glycogen granules and occasionally, some pigments. The cells are usually arranged in groups of 2 to 8 having a common capsule and thus they indicate their origin from a single cell by the process of cell division. The cells towards the surface beneath the perichondrium are slightly flattened and run parallel to the surface; those in the deeper plane are arranged in columns at right angle to those in the surface layer.

Fig. 45. Microphotograph of a Hyaline cartilage.

The intercellular ground substance. The ground substance in the hyaline cartilage is *homogeneous* and plenty in amount although it contains a network of very fine collagen fibres. In spite of the presence of fibres the homogeneity of the matrix can be explained by the fact that the fibres have the same refractive index with the substances (chondromucoid and chondroalbuminoid) which intervene between the fibres and act as cement amongst them (the cementing matrix can be removed by maceration to expose the fibres). Thus the intercellular substance consists of a cementing matrix and a fibrous matrix.

Distribution. As already mentioned most of the skeletal frame-work of the body the foetus is preformed in hyaline cartilage and after birth its persistence is und in the following:

(1) Articular cartilage.
(2) Epiphysial cartilage.
(3) Costal cartilage.
(4) Cartilages of the nose.
(5) Cartilages of the larynx except the epiglottis, cuneiform and corniculate cartilages.
(6) Cartilages of trachea and bronchi.

Nutrition. In the adult the hyaline cartilage has no blood vessels, no lymphatics nd no nerves. It derives its nutrition from the tissue fluid derived from the perinondrial blood vessels.

Growth. The growth in hyaline cartilage is well manifested in the foetus partiularly and during growing period. Two types of growth, *appositional growth* and *iterstitial growth* are usually found to occur in a growing cartilage. Appositional rowth takes place by proliferation of the chondrogenic cells at the inner layer of the erichondrium whereas interstitial growth takes place by proliferation of the young ells at the deeper zone of the cartilage.

Repair. The hyaline cartilage, when injured, is repaired mostly by proliferation f the cells of the perichondrium. Regeneration may, however, occur by metaplasia f the adjacent connective tissue cells.

Vital reactions of hyaline cartilage. (1) When a hyaline cartilage is injured, reeneration takes place by reparative processes as described above. (2) Both adult nd growing cartilages have no power to grow in a culture medium but when a ragment of growing cartilage is embedded in the brain, the fragment is seen to be ransformed into bone. (3) When a cartilage is deformed by long continued mehanical pressure, the change in shape obtained by such effects is permanent. This daptive change suffered by the cartilage is due to re-adjustment in the size of the chondrones which become smaller in the regions of the pressure points.

The elastic cartilage. The elastic cartilage consists of typical encapsulated cartilage cells and intercellular ground substance which contains in addition branchng elastic fibres which form anastomosing network around the cells. The fibres nearer to the surface are continuous with the perichondrium.

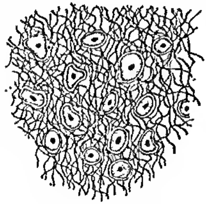


Fig. 46. Elastic Cartilage

Fig. 47. Structure of an intervertebral disc (Microphotograph)
Note the lamellar pattern of the fibrous tissue with the cartilage cells around the nucleus pulposus.

Distribution. The elastic cartilage is found in those places where the function of "Stretch and recoil" is a necessity. Thus it is found in the walls of the external auditory meatus, external ear, pharyngo-tympanic tube, epiglottis, cuneiform and corniculate cartilages of the larynx.

The white fibrocartilage. The white fibrocartilages differ from the hyaline and elastic cartilages in that it has no perichondrium and its intercellular substance contains dense bundles of collagen fibres. The cells are usually scanty and wide apart. They are typical cartilage cells with capsules. At the periphery its fibres merge with the surrounding connective tissue fibres.

Distribution. The white fibrocartilage is found in those places where great strain with rigidity and some amount of elasticity is required. Thus it is found in the intervertebral disc, interarticular disc or menischi, symphysis pubis and at the attachment of some of the tendons and ligaments to the bones.

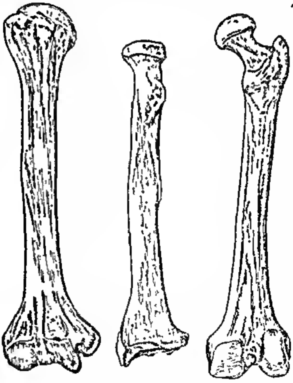
BONES

Bone is the hardest of all tissues and is a variety of vascular connective tissue where the organic and inorganic materials come into intimate combinations so as to form an integrated living structure. They are variously oriented as regards their shape and size, and are articulated in an orderly form to make the skeletal basis or the *skeleton* of the body. In man, and in most of the other higher vertebrates, the skeleton is found to be confined within the body and is known as *endoskeleton*. In some other vertebrates as for example the tortoise, the skeletal framework is found both externally—*exoskeleton*, and internally—*endoskeleton*. In man the exoskeleton is represented by the enamel of the teeth, and the nails. Developmentally, the skeletal framework is found to be associated with the development of the body wall as well as with the development of the visceral arches. Therefore, the skeleton may also be divided into *somatic* and *visceral skeleton*. The somatic skeleton consists of bones of the trunk, limbs and the skull. The visceral skeleton consists of the mandible, hyoid, auditory ossicles and the cartilages of the larynx. It may also be subdivided into *axial* and *appendicular skeleton*. The bones of the head, neck and the trunk are included in axial skeleton whereas the bones of the limbs are included in appendicular skeleton. Thus the subdivisions of the skeleton may be summarised as below:

(A) **According to location**
- (i) Exoskeleton.
- (ii) Endoskeleton.

(B) **Developmentally**
- (i) Somatic skeleton.
- (ii) Visceral skeleton.

(C) **When compared to "a stem with appendages"**
- (i) Axial skeleton.
- (ii) Appendicular skeleton.



Humerus Radius. Femur.

Fig. 48. A few long bones.

Classification of bones. Bones that build up human skeleton are altogether 206 in number including the auditory ossicles and the patella. They may be classified as follows:

According to development

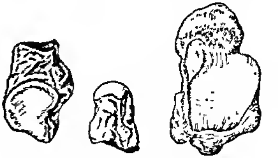
(*a*) *Membrane bones.* Bones that develop from membrane fall under this subgroup. Examples: Parietal and frontal bones.

(*b*) *Cartilage bones.* Bones that develop in cartilage are included in thi sub-group. All long bones (except the clavicle which though a long bone develops in membrane) such as radius, ulna, tibia, femur etc. are examples o cartilage bones.

(*c*) *Membrano-cartilaginous bones.* These bones develop partly from membrane and partly from cartilage, as for example, temporal bone, occipital bone.

According to shape, size and consistency

(*a*) *Long bones.* Each long bone consists of two expanded ends and a narrower intervening portion known as the shaft. The shaft of all long bones (except the clavicle) is *preformed in cartilage which ossifies from primary centres of ossification.* The *expanded ends of the long bone ossify from secondary centres.* Shaft of each long bone consists of a cavity within known as the *medullary cavity* except the clavicle, which, though a long bone, develops in membrane and has no medullary cavity. Examples: Femur, Tibia, fibula, humerus, ulna, radius etc.

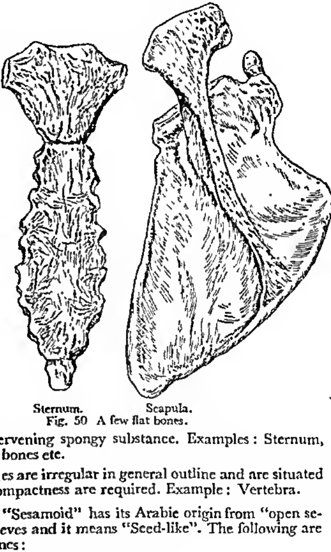


Cuboid. Capitate. Talus.

Fig. 49. A few short bones.

(*b*) *Short bones.* These are small, polyhedral bones whose length and breadth are almost equal. Each short bone consists of a spongy substance internally with a thin layer of compact bone externally. Examples: Carpal and tarsal bones.

(*c*) *Flat bones.* These are expanded or elongated plates of bone, lighter in comparison with their size and are usually developed from membrane. Each consists of two thin walls of compact substance and an intervening spongy substance. Examples: Sternum, ribs, scapula, parietal and frontal bones etc.



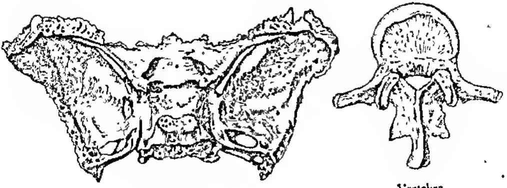
Sternum. Scapula.

Fig. 50 A few flat bones.

(*d*) *Irregular bones.* These bones are irregular in general outline and are situated in those places where strain and compactness are required. Example: Vertebra.

(*e*) *Sesamoid bones.* The term "Sesamoid" has its Arabic origin from "open sesame" of Alibaba and the forty thieves and it means "Seed-like". The following are the characteristics of sesamoid bones:

(*i*) It develops within the tendon of a muscle.
(*ii*) It has no periosteum.
(*iii*) It ossifies from the secondary centre of ossification.
(*iv*) It has no Haversian system.



Sphenoid. Vertebra.

Fig. 51. A few irregular bones.

Types of sesamoid bone:

(i) Intra-tendinous—that which develops within a tendon. Example: Patella, develops within quadriceps femoris tendon.

(ii) Periarticular—that which develops in the articular capsule of a joint. Example: The sesamoid bones of the metatarso-phalangeal joint of the great toe.

Patella

Fig. 52. A sesamoid bone

Maxilla.

Fig. 53 A Pneumatic bone containing a large air space.

(*f*) *Pneumatic bones.* These bones possess a hollow space within their body which contains air. They are chiefly present in close proximity to the nasal cavities and directly or indirectly communicate with the same.

(*g*) *Supernumerary or accessory bones.* Where there are more than one centre of ossification (secondary centre), some of the centres may fail to unite with the rest of the bone and may persist as a separate piece known as supernumerary or accessory bone.

According to gross or macroscopic structure

(*a*) *Compact bones.* The shaft or body of all long bones is a compact bone. When a longitudinal section is made through a long bone it is found to contain a central cavity within its shaft known as the *medullary cavity* which, in the recent state in post-natal life, is filled up with a semisolid substance known as the *yellow marrow* and in prenatal life, by red marrow. Externally it is clothed by a membranous sheath known as *periosteum* and internally, the medullary cavity is lined by a similar membrane-like structure known as the *endosteum*. In between the endosteum and the periosteum there is a thick layer of ivory-like compact substance, the compact bone, which is responsible for the hardness of a long bone. The ends of long bones are cancellous or spongy type of bone and contain red marrow in the recent state in their interior.

(*b*) *Spongy or cancellous bones.* They have a thin outer shell of compact substance and a network of lamellae of bone or bony trabeculae within. Their inter-trabecular spaces are occupied by the red marrow in the recent state. Examples: Flat, short, and irregular bones and the ends of the long bones are of this type.

(*c*) *Diploic bones.* Most of the cranial bones are diploic types and consist of an inner and an outer compact layer known as *inner* and *outer table* respectively, and

an intervening porous layer. The irregular spaces in the porous layer are occupied by a spongy substance which consists of diploic veins and marrow substances. The irregular spaces containing the diploic veins are known as *diploic spaces*. The *outer table of a* diploic bone is thicker than the inner one.

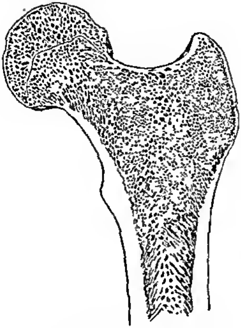


Fig. 54. A section through upper end of Femur showing spongy character at the end and compact layers and medullary cavity opposite the shaft.

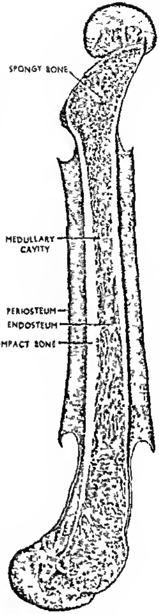


Fig. 55 A section through Femur showing periosteum and endosteum.

According to microscopic structure

(*a*) Lamellated bone.

(*b*) Haversian bone.

(*c*) Fibrous bone.

(*d*) Dentine.

(*e*) Cement.

(*a*) *Lamellated bone*. All spongy or cancellous bones and new bones in making are lamellated bones microscopically. Here the bony lamellae are arranged in the form of anastomosing trabeculae containing irregular spaces between them which are lined by endosteum. The small spaces between adjacent lamellae are occupied by the bone forming cells, the *osteoblasts*, and are known as *lacunae*. Minute channels known as *canaliculi* spread out from the lacunae and communicate with the inter-trabecular spaces and with other lacunae. These canaliculi are occupied by the protoplasmic processes of the osteoblasts in the recent state. The lamellated bones have no Haversian system.

(*b*) *Haversian bone*. All compact bones, as for example the bodies of long bones, are examples of Haversian bones. These bones show certain distinctive features in their lamellae formation, density and vascular pattern. When a transverse section through the shaft of a long bone of an adult is examined under the

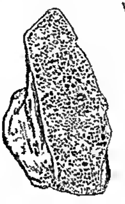


Fig. 56. A section through calcaneum showing spongy type of bone.

Fig. 57. A section through parietal bone showing inner and outer table and diploie.

microscope the following features are noticed:

Close to the surface beneath the periosteum the lamellae are arranged in flat layers in conformity with the disposition of the periosteum and these lamellae are called *circumferential lamellae.* On a deeper plane the lamellae are arranged concentrically around minute canals known as the *Haversian canal* and these lamellae which lie around the Haversian canal are called the *Haversian lamellae.* The Haversian canals branch and anastomose with each other and pass to the surface as well as to the marrow cavity. Each canal with its series of encircling lamellae constitutes what is known as *Osteone* or *Haversian system.* In between the Haversian systems there are some irregularly arranged indefinite form of lamellae known as the *interstitial lamellae* or *ground lamellae.* Between two adjacent Haversian lamellae are minute oval cavities known as the lacunae. From the lacunae a series of minute channels spread out in all directions through the matrix and these minute channels are called the *canaliculi.* These canaliculi communicate with the adjacent lacunae by piercing through the lamellae, and finally from one lacuna to the other they establish communication with the Haversian canal. *Thus, to summarise, a compact bone is found to consist of three types of bony lamellae, the circumferential lamellae, Haversian lamellae and the interstitial lamellae, and the Haversian canal, lacunae and canaliculi.*

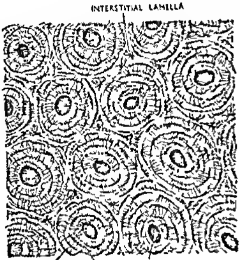


Fig. 58. Structure of Haversian bone.

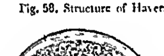


Fig. 59. A transverse section of Femur showing Lamellar arrangement (Diagrammatic).

The *Haversian canal* in the recent state is found to be occupied by blood vessels, lymphatics, nerves, a few wandering cells from the marrow and a few osteogenic cells (osteoblast). The osteogenic cells form a lining around the canal and thus intervene between the bony substance and other tissues contained within the canal.

The *lacuna* or the space in between the lamellae is fully occupied by an osteocyte which sends out protoplasmic processes through the canaliculi and these processes become continuous with the similar processes from the neighbouring cells.

Thus from the nature of the structure of a bone it is evident that the bony tissue is completely porous through the system of Haversian canal, lacunae and the canaliculi in each Haversian system. It is also evident that a true cellular syncytium of the osteogenic cells together with blood vessels and nerves pervade through each Haversian system. The basis of the osteogenic cells explains the osteoblastic activity (bone forming activity) during the repair of a bony tissue while the blood vessels and nerves are concerned with the nutrition of the tissue.

(*c*) *Fibrous bone.* This is a variety of bony tissue where the surface of the bone is pervaded by a dense network of fibrous bundles which are continuous with the fibrous tissue of the surrounding periosteum and therefore, the periosteum is difficult to be stripped off from the surface of such bones. The diaphysis of a growing bone is a variety of fibrous bone and the Sharpey's fibres in the adult bone represent the fibrous pattern of the young bone. In reptiles and amphibia most of the bones are fibrous types.

(*d*) *Dentine.* The portion of a tooth that intervenes between the enamel (over the crown) and the cement (over the root), externally, and the pulp cavity, internally is known as *dentine. Though a variety of bone-tissue, it has no bone cells or any other cells or lacunae.* It is ivory-like and is much harder than the bone. Structurally it consists of collagen fibres that run along its long axis and are embedded in a calcified ground substance. Its wall is perforated by innumerable small canaliculi known as *dental tubules.* Each dental tubule begins at the pulp space and proceeds across its wall to deep aspect of the enamel or cement. In its course towards the enamel or cement it gives out a series of branches and becomes gradually narrower. Each dentinal canal or dental tubule contains a protoplasmic fibre, *Tomesfibre* which is the process of an odontoblast contained within the pulp space. The wall surrounding each dental tubule is comparatively harder and denser than the rest of the dentine and is usually known as *Neumann's dental sheath.*

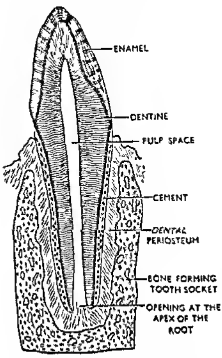


Fig. 60. A section of tooth showing its structure.

(*e*) *Cement.* The cement lines the dentine at the root and intervenes between the dental periosteum and the dentine. Structurally it consists *of bone cells and collagen fibres which lie in a calcified ground substance which is continuous with the dentine.* The cement is lined externally by the *dental periosteum* the fibres of which are engrafted externally to the wall of the alveolar socket and internally to the wall of the cement.

Periosteum. Except over the articular surfaces, bones are enclosed within a sheath of tough membrane known as the *periosteum.* In long bones the periosteum is easily separable from the surface except close to the ends and over the areas of muscular attachments where it is firmly adherent to the surface of the bone. Near the articular margin at the ends, the periosteum is continuous with the capsule of the joint from the articular margin.

Structure. The periosteum consists of two layers, an outer fibrous layer and an inner osteogenic layer. The outer fibrous layer consists of white fibrous tissue mostly with a few elastic tissue embedded in it; it also contains numerous blood vessels, lymphatics and nerves. The inner osteogenic layer is made up of comparatively looser connective tissue which is highly vascular. The cells of this layer are osteogenic, that is, they are capable of showing osteoblastic activity (bone forming activities) in times of need and during growing period. It is for this reason that the inner layer of the periosteum is called the *osteogenic layer.* At certain places, particularly opposite the attachment of muscles and in the region of the ends in long bones, fibrous processes from the periosteum penetrate through the substance of the bone and these periosteal processes are known as the *perforating fibres of Sharpey.* The deeper portions of these perforating fibres of Sharpey become ossified and it seems as if the muscle, the periosteum and the superficial lamellae of the surface bone, all have been "nailed" together to secure better anchorage.

Function. The periosteum provides nutrition to the surface bone (*nutritive function*); it helps in bone formation during growth and repair of bones (*osteogenic function*); it serves as a *limiting membrane* which prevents overgrowth of bone; the perforating fibres of Sharpey provide better anchorage for the muscles as well as for

the superficial lamellae of surface bone. It serves for the attachment of the muscles, tendons and ligaments.

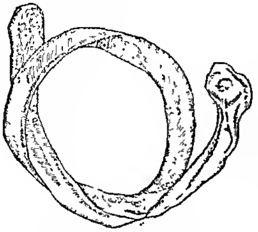


Fig 61. Diagram of a soft rib forming a knot.

Physical properties of bone. A fully formed bone is hard and at the same time elastic but when it is kept in weak acid solution, for some time *it loses its hardness* and becomes elastic, so much so, that when a rib is treated in this way a knot can be tied in it. The reason for this is that the mineral matter of the bone is dissolved out due to prolonged immersion in acid solution and only the animal matter is left behind which is elastic. Thus it appears that the hardness of a bone is due to its contained mineral matter. Similarly, a bone when burnt, it loses its animal matter but the minerals are left behind due to which, though burnt, the bone maintains its shape but becomes brittle.

Chemical composition of bone. (*i*) Animal matter—33·3 per cent (It gives resiliency and tenacity to the bone). (ii) Mineral or inorganic substances in the form of cal phosphate, cal. carb., mag. phos., cal. flouride, etc.—66·7 per cent.

Functions of bone. (1) It acts as a supporting framework. (2) It serves as levers for muscles. (3) It is protective in nature. (4) It contains red marrow which is the factory of R.B.C. (5) It is the store house of calcium.

Morphogenesis of bone. A bony tissue consists of bone cells embedded in a calcified matrix which forms the main bulk of the tissue.

Bone cells. Mesenchymal cells differentiate into osteoblasts which later on change into adult bone cells (Osteocytes). The osteoblasts during the later part of its development lay down the matrix which surrounds the cells and thus the bone cells lie in small, round or oval spaces, the *lacunae*. Each bone cell sends out protoplasmic processes which pass in all directions through the matrix forming *canaliculi* in the matrix.

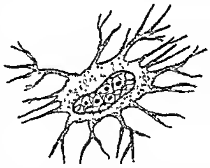


Fig. 62. An osteoblast.

Matrix. The matrix is composed of both *inorganic* and *organic substances*. The inorganic substance is made up of calcium, phosphorus and a trace of magnesium, etc. and the ratio between the calcium and phosphorus is almost constant in normal conditions The organic part of the matrix is made up mostly of substances which resemble collagen of the connective tissue and is known as *ossein*. Mucoid and albumoid substances are also present in traces and are known as *osseomucoid* and *osseoalbumoid* substances respectively.

During the early period when the osteoblasts begin to form the matrix interwoven fibres are seen to appear in the matrix which (fibres) are cemented together by an amorphous material. Later on the fibres are grouped into osteocollagenous bundles which are arranged to form separate individual lamella; fibres of one lamella may pass on to the other and establish a firm bond of union between the lamellae; the bony lamellae thus formed are variously arranged and it is the arrangement of the lamellae that determines the consistency of a bone. Thus, when the lamellae are mainly arranged in trabecular formations in varying patterns spongy or cancellous

type of bone results, and when they are arranged mostly in concentric layers, compact type of bone results.

Ossification of bone. The process of gradual bone formation is known as ossification. Mesenchymal cells, which differentiate into osteogenic cells, prior to actual ossification, form a structural basis which may be either a membrane or a cartilage *in which ossification is to take place. Depending on the formation of this* structural basis in the initial stage the process of ossification may be classified into *intramembranous* and *intracartilaginous types.*

Intramembranous ossification. "Intramembranous ossification", as the name implies, is the process in which ossification *starts directly* in a membrane without having passed through cartilaginous stage. In the early embryonic life, the region, in which a membrane bone is to develop, shows condensation of the mesenchymal cells. Soon blood vessels rapidly proliferate within the condensed area so that it becomes more vascular. Later on the mesenchymal cells behave like the connective tissue in which collagen fibres are found to be embedded amongst the cells, thus a membrane-like structure is formed—bones in making in membrane. Subsequently the mesenchymal cells at the centre of the membrane differentiate into bone forming cells (osteoblasts) which are characterised by larger size with larger amount of basophilic cytoplasm. As soon as the osteoblasts are formed the matrix also shows signs of specialisation. On the pre-existing fibrillary basis of the matrix a new solid type of matrix (calcified hony matrix) is added and as a result, the newly formed osteoblasts become burried in the matrix. Concurrently, the cells towards the surface multiply by mitotic division and some of the resulting daughter cells become osteogenic and form the osteogenic layer of the periosteum while others show fibroblastic changes and form the outer fibrous layer of the periosteum.

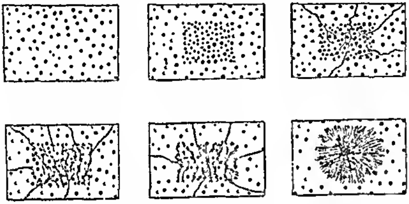


Fig. 63. Stages of Intramembranous ossification (Diagrammatic).

Ossification starts at different points in the centre of a future membrane bone to form the centres of ossification which coalesce together and then spread radially in all directions. *Pari passu* with these changes remodelling processes by the osteoclasts continue simultaneously until a regular bony pattern is formed.

Intracartilaginous or Endochondral Ossification. Mesenchymal cells form the primary basis for both intra-membranous and intra-cartilaginous types of ossification. In intramembranous ossification the mesenchymal cells differentiate both directly, and indirectly by mitotic division into osteogenic cells whereas in endochondral ossification, as in a long bone, the mesenchymal cells first differentiate into cartilage cells and cells forming the perichondrium, then there is calcification and degeneration of the main mass of the cartilaginous model; then the osteogenic cells differentiate from the deeper layer of perichondrium (which has potentiality both for osteogenic and cartilage cells) and the degenerated cartilaginous mass is replaced by bone by ossification. Thus endochondral ossification can be studied under the following heads:

(1) *Stage of mesenchymal condensation or formation of bony rudiment.* This is the earliest stage of endochondral ossification in which in the region of the future bone formation the still undifferentiated mesenchymal cells are

massed together to form the undifferentiated *mesenchymal condensation* or the *bony rudiment.*

(2) *Stage of chondrification.* In this stage the cells of the condensed mesenchymal mass are converted into cartilage cells to form the cartilaginous basis of endochondral ossification.

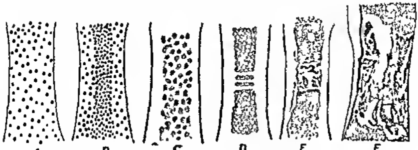


Fig. 64. Stages of Endochondral ossification (Diagrammatic).

The cells of the bony rudiment are soon found to have an appearance intermediate between fibrous and cartilaginous cells and this differentiation is said to form *procartilage.* Then the cells in the central zone become elongated and lie in a direction at right angle to the long axis of the bony rudiment and each acquires a capsule within which the cell multiplies by cell division, and thus adds to the length of the rudiment. Concurrently with this change in the central zone, the mesenchymal cells on the surface opposite the centre of the rudiment also become elongated and are disposed longitudinally. These elongated cells on the surface differentiate into fibroblasts to form the *perichondrium.* Then the process extends towards the ends of the rudiment and thus the perichondrium surrounds the whole mass except the extreme ends which enter into the formation of joint. *Pari passu* with the formation of the perichondrium the whole mass within the perichondrium becomes cartilaginous—the mesenchymal cells changing directly into cartilage cells and the stage of chondrification thus ends.

Stage of calcification and degeneration of the main mass of the cartilage.

The cartilage cells in the centre of the cartilage become enlarged and vacuolated and they become soon calcified due to deposition of calcium salts. The cells adjacent to the calcified area proliferate rapidly and arrange themselves in rows or columns which extend towards the ends. The process of calcification gradually extend into the adjacent areas and the cartilage cells become burried in the calcified matrix. The cartilage cells being burried in the calcified matrix are deprived of their nourishment and die rapidly due to autointoxication; with the disappearance of the cartilage cells empty spaces are formed which are known as *primary areolae.*

Fig. 65. Microphotograph of a growing long bone.
Note the formation of the primary areolae in the degenerated cartilage mass

Stage of ossification. Prior to the start of ossification the perichondrium differentiates into outer fibrous and inner cellular layers. The cells of the inner layer differentiate into osteogenic cells (osteoblasts) which begin to form bone beneath the periosteum and thus the calcified cartilage mass

is ensheathed by a layer of surface bone underneath the periosteum. Concurrently with the formation of the lamellae of surface bone new vascular tissue (which differentiates in situ) together with osteoblastic and other cells forms periosteal buds which erode through the calcified cartilage mass towards its

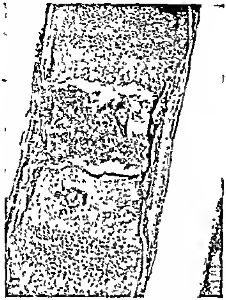


Fig. 66. Microphotograph of a growing long bone.
Note that the periosteal bud eroding into the calcified cartilaginous mass.

Further stage of figure 66.
Fig. 67. Microphotograph of a growing long bone.

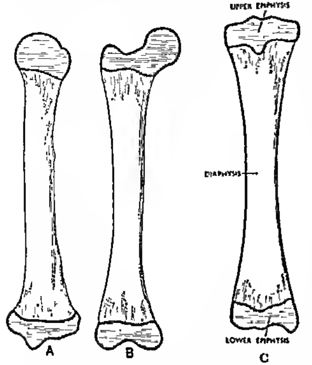
centre. The periosteal bud during the process of erotion gives rise to the formation of numerous large empty spaces, known as the *secondary areolae* the walls of which are soon invaded by bony trabeculae. Concurrently with the formation of the surface bone, periosteal buds convert the inner calcified cartilage matrix into bone and thus endochondral bone formation ends except at the ends of the long bone (epiphysis) which remain cartilaginous and are ossified from the secondary centre of ossification after birth. The epiphysial cartilage which intervenes between the cartilaginous epiphysis and the diaphysis also remain unchanged until the growth in longitudinal direction of the bone is completed.

Formation of epiphysial cartilage (in case of long bone only). It is already learnt that the cells in the central zone of the mesenchymal condensation directly change into cartilage cells while those cells which lie towards the ends of the future bone multiply by mitotic division and then change into cartilage cells. These young proliferating cartilage cells give rise to the formation of the epiphysial plate and the epiphysis. The cells on the epihysial surface of the epiphysial cartilage continuously proliferate until growth in longitudinal direction is completed. The mature cells on the opposite surface of the epiphysial cartilage degenerate and their places are taken up by extension of bone formation from the diaphysis.

In conclusion, it may be said that, although, only for better understanding the process of endochondral ossification has been divided into several stages, the changes come in so quick succession that clear-cut demarcation between the stages is difficult to be ascertained. The stage of formation of epiphysial cartilage is only associated with those bones which have epiphyses.

Parts of a growing long bone. A growing long bone consists of two cartilaginous ends known as the *epiphyses* which ossify from secondary centres of ossification and an intervening portion known as the *diaphysis*. The epiphysis and the diaphysis form two distinct portions which are united together through the medium of a plate-

like cartilage known as the *epiphysial cartilage.* The portion of the diaphysis adjacent to the epiphysis is called the *metaphysis.*



A growing humerus. A growing femur. A growing tibia.
Fig 68 Parts of a growing long bone.

DIAPHYSIS. The tubular shaft or body of a growing long bone which intervenes between the two epiphyses or the cartilaginous ends is called the diaphysis. It ossifies from the primary centre of ossification. Macroscopically, on transverse section, it presents the same features as that of the shaft of an adult long bone. The periosteum is firmly adherent to the surface of the bone due to the presence of bundles of collagenous fibres on its surface with which the periosteum is continuous.

Microscopically the diaphysis differs from the shaft of an adult long bone in having no Haversian system and its surface presents collagenous bundles of fibres which are continuous with the periosteum. Thus microscopically it is a fibrous bone.

METAPHYSIS. The portion of the diaphysis adjacent to the epiphysial cartilage is called the metaphysis. It consists of soft vascular bony tissue where growth activities are highly manifested.

Importance of metaphysis:

(1) Growth activities are predominantly marked in this area.
(2) This is the most vascular part of the long bone because most of the blood vessels supplying the bone anastomose in this area.
(3) Most of the muscles of the joint are inserted in this area.
(4) This area is more often liable to injury because it is more exposed to muscular strains due to the attachment of the muscles in this area.
(5) Sometimes the metaphysis extends within the line of attachment of the capsular ligament and infection of one may spread to the other.

Metaphyses which are partly or wholely intracapsular:

(1) Upper and lower ends of humerus and femur.
(2) Upper end of radius.
(3) Lower end of ulna.

Special features of metaphysial blood vessels of long bones. The cells on the diaphysial side of the epiphysial cartilage degenerate while those on its opposite side proliferate. Growing osteoblasts together with sprouting blood vessels invade these degenerated cartilage cells and replace them with new bones. These blood vessels from the metaphysis which invade the epiphysial plate are *end arteries, comparatively wider in calibre* and show *peculiar bulbous dilatation at their ends* ("Hair-pin terminus"). These special features of metaphysial blood vessels are responsible for bringing about some form of stagnancy in the circulation in this part of the bone and as a result, haematogenous infection usually tend to localise in this part producing a condition known as osteomyelitis (Juvenile type).

EPIPHYSIS. The epiphysis is that portion of a long bone which develops from secondary centre of ossification. This is present only in cases of long bones; in long bones usually there are two epiphyses, each being present in the corresponding end of the bone and up to certain period of age they remain separated from the rest of the bone by a plate-like cartilage known as the epiphysial cartilage. Later on, the epiphysial cartilage undergoes ossification and the epiphysis and the rest of the bone becomes osseously continuous with one another. In certain long bones there is only one epiphysis, as in the case of metacarpal and metatarsal bones.

Usually there are three types of epiphysis, namely *pressure epiphysis*, *traction epiphysis* and *atavistic epiphysis*. The *pressure epiphyses* are usually found at the ends of long bones (the expanded ends of long bone) such as, humerus, femur, tibia, fibula, ulna, radius etc., and are protective in nature during growing period when they are specially adapted to protect the more important epiphysial cartilage from the effects of stress and strain. "*Traction epiphysis*" as the name implies, comes into being as a result of pull by the muscle attached to it, as for example, trochanters of the femur.

Atavistic Epiphysis. The atavistic epiphysis (atavus=an ancestor) represents such bones that have retrogressed mostly with the progress of evolution and that their rudimentary remnants, which fail to show separate existence, are found to remain fused with adjacent bones, as for example, the coracoid process of scapula. In reptiles the coracoid bone forms an independent element of the pectoral girdle and is a relatively large bone. In mammals with the change in mechanism and function of the shoulder girdle the coracoid bone has retrogressed considerably and is represented by a small subcoracoid secondary centre which develops in association with the scapula. The pubic crest, the margins of the ischiopubic rami and the ischial tuberosity are also known to be formed atavistically and are representative of the median pelvic bar. The epiphysis of the calcaneum and the scaly epiphysis of the olecranon also fall under atavistic epiphysis (Parson).

Aberrant Epiphysis. Normally the metacarpal bones have only one epiphysis at their distal end except the first which has a proximal epiphysis. Occasionally the first metacarpal may have a distal epiphysis in addition to its proximal one which is normally present. The distal epiphysis for the first metacarpal when it exists, is called its aberrant epiphysis. Similarly the second and the fifth metacarpals as well as the second and fifth metatarsals may develop aberrant epiphysis at their proximal end.

Laws of ossification

(1) Ossification may begin either from a membrane or from a cartilage.

(2) Ossification begins from a particular point and spreads out in a radiating manner to different portions of the bone. The point from which first ossification starts is known as the *centre of ossification*.

(3) Centre of ossification may be *primary* or *secondary*.

(4) *Primary centres* may be single or multiple and usually appear before birth with the exceptions of the *os cuneiformis* and *os navicularis*.

(5) Secondary centres are usually multiple and appear after birth with the exception of the *lower end of the femur* where secondary centre of ossification appears before birth.

(6) Primary centres, when multiple, all appear simultaneously.

(7) Secondary centres, when multiple, do not appear simultaneously but appear at different dates of life.

(8) The epiphysis which begins to ossify first, unites with the diaphysis last and vice versa (Law of union of epiphysis). The only exception to this is the lower end of the fibula where ossification begins earlier and unites with the body earlier.

The union of the epiphysis is guided by the direction of the nutrient artery and the epiphysis towards which the nutrient artery is directed unites with the diaphysis first but here the ossification starts later in comparison with the other end. In other words both ossification and union of the epiphysis are mainly guided by the direction of the nutrient artery.

(9) The centre of ossification for the epiphysis appears first in the growing end of the bone.

(10) The different centres of ossification of an epiphysis unite together first before union with the diaphysis.

Nutrition of bones. A bone gets its nutrition from the blood which reaches it through blood vessels in different ways. The mode of distribution of blood vessels differs according to the type of bone. Thus a long bone has a definite system of blood supply which differs from that of a flat bone and other types of bone and as such the blood supply of bones has been described separately under separate heads.

BLOOD SUPPLY OF LONG BONES. A long bone gets its blood supply from the following sources:

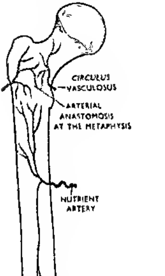


Fig. 69. Blood supply of a long bone.

(1) *Nutrient artery.* The nutrient artery enters the long bone through the nutrient foramen which is present in the shaft of a long bone. The artery becomes very much tortuous before it enters into the nutrient foramen and this tortuosity saves the artery from being injured during active muscular movement and also it prevents the blood pressure to be altered during the active movement. On entering into the bone the artery soon breaks up into two branches —one for each end of the bone. Each artery then again breaks up into smaller parallel branches which run into the metaphysis.

(2) *Juxtra-epiphysial blood vessels.* These are small arteries derived from the arterial anastomosis around the joint and they enter the bone by piercing it opposite to the attachment of the capsular ligament and then pass to the metaphysis where they end.

(3) *Epiphysial blood vessels.* They are also derived from the arterial anastomosis around the joint, they penetrate into the epiphysis and end by supplying it.

(4) *Periosteal blood vessels.* These blood vessels lie within the periosteum from which twigs are given off which pierce the compact part of the bone and end by supplying the superficial portion of the bone.

BLOOD SUPPLY OF SHORT LONG BONES. The short long bones (metacarpals, metatarsals etc.) have only one epiphysis and one metaphysis. The system of blood supply in these bones are as follows:

(1) *Nutrient artery.* It enters the bone through nutrient foramen and breaks up into several branches which freely anastomose to form plexuses and end by supplying the shaft of the bone.

(2) *The epiphysial and juxtra-epiphysial blood vessels* supply only the epiphysial end of the bone.

(3) At the end opposite to the epiphysis there is insufficient blood supply and some blood vessels resembling *epiphysial vessels* supply this end of the bone.

(4) *Periosteal blood vessels.* These form the principal blood supply of the bone after cessation of growth.

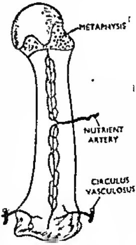


Fig. 70. Blood supply of a short long bone.

Applied Anatomy. Because the nutrient artery after entering the shaft of the bone breaks up into branches which form plexuses within the shaft, tuberculosis and syphilis of short long bones are so common in the shaft in contrast with the long bones where these diseases mainly affect the ends which are rich in blood supply.

BLOOD SUPPLY OF FLAT BONES. (1) *Nutrient artery.* It is very small and after entering the bone it breaks up into branches which ramify all through the bone.

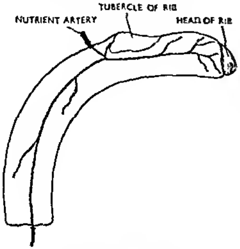


Fig. 71. Blood supply of a rib.

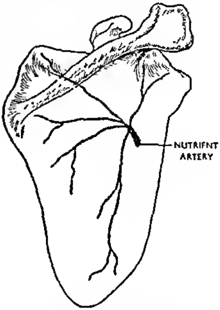


Fig. 72. Blood supply of Scapula.

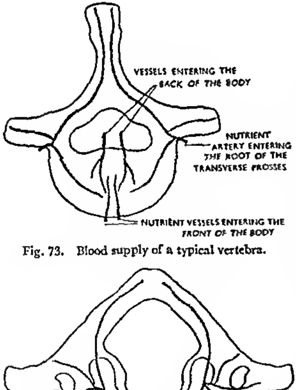


Fig. 73. Blood supply of a typical vertebra.

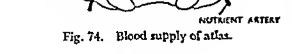


Fig. 74. Blood supply of atlas.

(2) *Periosteal vessels.* They form the principal sources of blood supply and are rich in number.

BLOOD SUPPLY OF I REGULAR BONES. (vertebrae). (*i*) Two large vessels enter into the body through an aperture on its posterior surface and break up into branches which supply the body. (*ii*) Smaller vessels also pierce the antero-lateral aspect of the body. (*iii*) One vessel enters the root of the transverse process and then divides into branches which pass to the lamina, pedicle, spine and the transverse process.

Applied Anatomy. In case of vertebra the body is richly supplied by blood vessels and consequently tuberculosis and syphilis are so frequent in the body of a vertebra.

Nerve supply of bones. Nerves supplying the bones are both myelinated and non-myelinated. They accompany the blood vessels to enter into the substance of the bone.

The lymphatics of bone. The lymphatics of bone are mostly confined to the periosteum and to the Haversian systems. There is no lymphatics in the marrow

The lymphatics of the Haversian system accompany the blood vessels entering the bone and they drain into the periosteal lymph vessels.

Growing end of a long bone. The growing end is that end of a long bone towards which the growth in length of the bone usually occurs. Thus it appears that the growth in length of a long bone does not occur equally on either direction but it proceeds in one direction mostly, or in other words, it is almost a one-sided growth and the end towards which it occurs is called the growing end. The growing end and the direction of the nutrient artery are closely inter-related. *The end which lies opposite to the direction* of the nutrient artery is the growing end of a long bone.

Direction of the nutrient artery. The direction of the nutrient artery in case of the long bones of the limbs can be ascertained from the saying "To the elbow I go, from the knee I flee". In case of ulna, radius, and the humerus the nutrient artery is directed towards the elbow joint, that is, in the humerus it is directed towards its lower end and in case of ulna and radius it is directed towards their upper ends. Similarly in the femur, tibia and the fibula the nutrient artery runs away from the knee, that is, it passes towards the upper end of the femur and towards the lower ends of the tibia and fibula.

Growth of Bone. The growth of a bone can better be studied in the case of a long bone. During growing period with advancing age a long bone is seen to gain in thickness as well as in length. The gain in thickness is accomplished by continuous surface accretion of bone beneath the periosteum and *pari passu* with the gain in thickness the medullary cavity enlarges by the continuous absorption of bone by the activity of the osteoclasts. The gain in length is found to be executed at the expense of the epiphysial cartilage at the ends of a long bone. The cells of the diaphysial surface of the epiphysial cartilage show signs of degeneration and at the same time process of ossification extends from the metaphysis and replace these degenerated cells by new bone. *Pari passu* with the degeneration of the cells on the diaphysial side, the cells on the epiphysial side of the epiphysial cartilage proliferate and thus the growth in length takes place at the expense of the epiphysial cartilage which degenerates on one side (their place being taken up by osteogenic tissue) and proliferates on the other. This process continues until full growth is attained when the cells on the epiphysial side of the epiphysial cartilage no longer proliferate and the extension of ossification from the diaphysis convert the epiphysial cartilage into bone and finally the epiphysis and diaphysis become osseously continuous with each other.

In case of bones of the vault of the cranium the gain in thickness is due to subperiosteal deposition of bone externally while continuous bone absorption occurs on their internal surface.

Factors associated with bone growth. The fundamental processes involved in bone growth are nutritional factors and hormonal influences.

Notritional factors. *Mineral Salts*—Several nutritional factors must be contained in the diet so that growth of bone may be normal. Deficiency of calcium and phosphorus, and to a less extent magnesium and fluorine affects the growth of the bone adversely during growing period. Deficiency of these salts in the adult leads to resorption of calcium from the bone leading to a condition known as *osteoporosis*. During growing period deficiency of these salts leads to retarded growth and irregular bone formation; the strength of the bone is also remarkably diminished.

Vitamin D. Vitamin D is an essential requirement towards satisfactory bone growth. Even if the diet contains calcium and phosphorus sufficiently, absence of vitamin D will lead to *ricket*, a condition which leads to stunted growth, irregular bone formation and manifestation of soft bone. It is believed that Vitamin D helps in absorption of calcium and phosphates from the intestines and keeps them in proper proportion in the blood. Experimental studies show that Vitamin D acts through parathyroid gland which it stimulates to elaborate its hormone.

Vitamin A. Vitamin A has also its important role in the control of normal bone growth. Recent experimental studies show that deficiency of Vitamin A during growing period leads to a condition in which the bone becomes thickened and rough; there are also superfluous growths, particularly at the margins of the foramina and at the sutures, leading to pressure symptoms and degenerative changes. It is further revealed that in areas where the osteoclasts are mainly concerned in remodelling of bone their number becomes remarkably scanty, on the other hand, osteoblasts show marked preponderance over the area of the superfluous bone growth. It has been suggested that Vitamin A controls the remodelling processes by the balanced distribution of the osteoblasts and osteoclasts.

Vitamin C. Vitamin C deficiency leads to a condition known as *scurvy* in which delay in healing processes, abnormal bony changes, haemorrhages and anaemia are characteristic features. It is known that vitamin C is responsible for the production of intercellular ground substances in the form of collagenous fibres in fibrous tissue, matrix of bone and cementing substance of the vascular endothelium. It has already been learnt that prior to calcification osteoblasts lay down collagenous matrix on which calcification takes place. Thus it may be observed that vitamin C controls the calcification of bone in making the fibrillary basis of collagenous fibres on which calcification is to take place.

Hormonal Influences. *Parathyroid*—The internal secretion of parathyroid body is essentially concerned with calcium metabolism and so with bone growth. This hormone in normal concentration maintains the calcium equilibrium between blood and tissues. Hyperconcentration of this hormone in blood leads to mobilisation of calcium from the bones which results in hypercalcimia. In hypercalcimia the blood calcium is enormously raised, excretion of calcium is increased and the bones are depleted of calcium and there is associated pathological calcifications. It is believed that calcium exists in blood in two forms, diffusible and non-diffusible. The amount of non-diffusible form of calcium in the blood is dependent on the amount of parathyroid hormone; there is an equilibrium between the diffusible and non-diffusible forms of calcium in the blood and the blood calcium in turn is in equilibrium with the calcium of bones. In hyperparathyroidism this non-diffusible form of calcium is greatly increased and consequently diffusible form of calcium is also increased (to keep equilibrium with non-diffusible forms) giving rise to high calcium content of blood. As the calcium content of the bone is in a kind of equilibrium with the blood calcium, calcium is mobilised from the bones to the blood. In hypoparathyroidism on the other hand there is defective calcification of bones, low calcium content of the blood and thereby tetany, rickets, spasmophilia etc. result. Thus parathyroid hormone must be in the blood in adequate amount so as to maintain normal growth of bone.

Thyroid. Removal of thyroid gland during growing period affects the growth in length of the long bones adversely and results in shortening of length. It is believed that thyroid hormone has no direct influence on bone growth but its absence affects their growth indirectly by depressing the general metabolism of the body.

Pituitary Body. The growth promoting hormone of anterior pituitary bears some definite relation with the skeletal growth. Hyperpituitarism during growing period, results in *gigantism* and after growing period, in *acromegally*. In experimental hypopituitism during growing period the epiphysial cartilage shows degenerative changes resulting in stunted growth whereas in experimental hyperpituitarism the epiphysial cartilage is seen to proliferate considerably resulting in increased growth. Thus it is evident that pituitary hormone (anterior pituitary) has definite control over the bone growth.

Testicle. Removal of testicle in man during growing period results in skeletal overgrowth and it is believed that testicular hormone delays the closure of the epiphysial cartilage and consequently delays union of epiphysis and diaphysis and thus results in skeletal overgrowth.

Vital reactions of bone. A living bone always reacts to stress and strain whether it is internal or external. Thus when internal strain is increased, as by removing the tibia from the leg, the fibula becomes thicker and stronger; similarly, when the internal strain is reduced, as in conditions of muscular paralysis, the bony trabeculae become thinner, and the lacunae and the Haversian canals become wider, and the bone becomes weaker, although the general form of the bone remains unaffected. In ricket, a condition where the bone becomes softened and bent, a strut of bone along the concave surface of the bend develops. Similarly, when a bone is subjected to external strain, as by applying pressure on the surface, absorption of bone occurs due to impaired blood supply, and a depression appears over the point of the pressure. The articular end of a bone which is lined by avascular articular cartilage does not show this change unless the cartilage is damaged. If the direction of the stress and strain changes due to some abnormal conditions or to some operative measures, the pattern of the internal construction changes and a bony reconstruction to suit the new condition of stress and strain takes place. If a bone is fractured it reacts in an ingenious way towards its repair (*see* regeneration of bone).

The osteoblasts and the osteoclasts are the bone-forming and bone-destroying cells respectively in a bone. The osteoblast never changes its creed of bone formation even when it is isolated from its normal abode. Thus whether it is cultivated in an artificial medium or it is transplanted to a tissue other than bone it continues to form bone.

Regeneration of Bone. Regeneration of bone after fracture represents almost the same processes in a modified way that take place in endochondral and intramembranous ossifications. Whenever there is a fracture it is associated with rupture of blood vessels contained within the bone as well as others from the surrounding soft tissues. The extravasated blood and the tissue fluids soon coagulate and this coagulum of blood and tissue fluid surround the fractured ends and occupy positions underneath the periosteum, within the medullary cavity (in case of long bone) and in between the fractured ends of the bone. The ruptured endothelial cells from the blood vessels soon proliferate and invade these coagulated masses and in no time the whole mass is vascularised and is converted into a granulation tissue. Thus a bond of union by soft tissue (pro-callus) is soon established within seven days between the fractured ends. Later on, osteogenic cells from the deeper layer of the periosteum, the Haversian canals and from the endosteum soon proliferate, and depending on the degree of vascularity of the local part, gives origin to two types of cells, osteoblasts and cartilage cells, the latter being developed in less vascular part. With the development of these cells calcification sets in and the calcified osteo-cartilaginous mass is called the *callus* which forms the basis of hard tissue union or the union by *callus*. The callus is seen to be formed underneath the periosteum, between the fractured ends and within the medullary cavity. The callus that lies externally underneath the periosteum is called the *external callus*, that within the medullary cavity, the *internal callus* and that in between the fractured ends is called the *intermediate callus*. This calcified osteo-cartilaginous mass, or the *callus*, is then invaded by the osteoblasts and the growing blood vessels and is replaced by true bony tissue in the same process as in endochondral ossification. Thus a bony union is established. Finally osteoclasts come into play to take up the task of remodelling, the superfluous growths are reabsorbed, the medullary cavity is reformed and true lamellar pattern with Haversian system is reformed.

The osteocytes or the adult bone cells which occupy the lacunae of the bone do not come at all in the regeneration of the bone, on the other hand they degenerate for within a few millimetre from the fractured ends.

BLOOD

Blood is the most essential vital fluid that permeates through all the tissues of the body in some form or other, infuses vitality to them by conveying nutritive elements and oxygen, dissolves out the injurious metabolites from them and makes them

thriving for the existence of the organism and for this, it is so often referred to as "life".

It is a variety of connective tissue in which the intercellular substance is a liquid and is derived from the mesodermal tissue. The cellular elements of blood consist of *red blood corpuscles, white blood corpuscles* and the *platelets* while its intercellular substance is a liquid which constitutes the *plasma.*

PROPERTIES OF BLOOD:

Colour. The colour of the blood varies according to its source. The arterial blood is bright-red in colour due to oxy-haemoglobin of R.B.C. whereas the venous blood is dark-red in colour due to reduced haemoglobin.

Consistence. Compared to distilled water blood is more viscous and this viscous consistence of blood usually goes by the name "*Viscosity of blood*". The more the viscosity of a fluid, the more is the resistance offered by it in its passage through a tube. Thus the viscosity of blood is a source of resistance to the flow of blood through the blood vessels.

The viscosity of blood is due to the presence of cellular elements (R.B.C., W.B.C. and platelets) and plasma proteins. It is about 5 times more viscous than the distilled water as is determined by the viscosimeter which is a specially made tube through which blood and distilled water are allowed to run separately and the time taken by each is noted and compared.

Re-action. Blood is alkaline in re-action with a *p*H of 7·4 on an average. The *p*H of blood may vary between 7·3 and 7·45 normally but in no circumstances it goes either above 7·8 or below 6·8.

Specific gravity. For clinical purposes, usually the venous blood is used for determination of the specific gravity. The specific gravity of the venous blood varies between 1,055 and 1,066 with an average of 1,056.

The specific gravity of blood is of definite clinical value in ascertaining its density and in making the estimate about the amount of fluid that would be required by a patient suffering from dehydration due to loss of body fluid either by excessive purgation, vomiting, haemorrhage or by some other causes. It is usually determined by putting a drop of blood into a fluid of known specific gravity. If the blood drop floats in the fluid it is of lower specific gravity than the fluid, if it sinks, it is of higher specific gravity, but if it neither floats nor sinks then it is of same specific gravity with the fluid. Usually glycerin and water mixture is used for this purpose. A series of mixtures of known specific gravity in ascending order are kept as stock solutions and then the specific gravity of blood is determined as stated above.

Osmosis and Osmotic pressure. If a liquid solution, *e.g.*, a solution of $CuSO_4$ in water, or alcohol in water, is kept in contact with a similar solution in different concentration, it is found that even without any stirring the two liquids intermingle with one another tending to form a uniform solution. This tendency for equalisation of concentration persists even when the solutions are separated from one another by means of a suitable semipermeable membrane, which is impermeable to the solute but is permeable to the pure solvent. In *this case the tendency asserts itself* by causing a preferential flow of the pure solvent from the side of lower concentration to the side of higher concentration. This process of preferential *transmission* of the solvent across a semipermeable membrane is called *osmosis.*

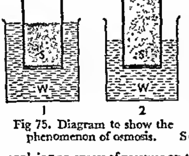


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Fig 75. Diagram to show the phenomenon of osmosis.

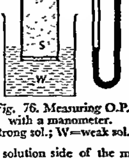


Fig. 76. Measuring O.P. with a manometer. S=strong sol.; W=weak sol.

If a porous pot impregnated by a *semipermeable membrane contains* a sugar solution and is immerged in water, the osmosis causes an accumulation of water inside the vessel causing a rise in the level of its liquid. This osmotic *flow* can be prevented by applying an excess of pressure on the solution side of the membrane. This excess pressure required just to prevent osmotic flow is called the *osmotic pressure.*

Osmotic pressure of blood. Any fluid having the same molecular concentration with the blood is known as *isotonic solution*, when lower than that of blood it is known as *hypotonic* solution, and when higher, it is known as *hypertonic solution*. When two solutions are isotonic with each other they are of equal osmotic pressure and therefore the solutions are physically compatible with each other. Both the red blood corpuscles and the plasma are of equal osmotic pressure (the corpuscular cell membrane acting as a semi-permeable membrane) and therefore the plasma forms a compatible fluid for the R.B.C. The osmotic pressure of blood equals to that of ·9 per cent sodium chloride solution and therefore the latter is isotonic with blood or in other words it is a isotonic solution.

Coagulation of blood. When blood comes out from the blood vessels, either from a cut or when it is withdrawn from a vein with a syringe, it soon loses its fluidity and forms a jelly-like solid mass known as the *clot*. The process by which the blood is coagulated is known as the *coagulation of blood*. After the blood has been coagulated the clot retracts squeezing out a clear yellowish supernatant fluid known as the *serum*. When a sample of blood in a test tube is mixed with some anti-coagulant (cal. oxalate, sodi citrate etc.) the blood remains fluid indefinitely and when it is kept standing for sometime the cellular elements of the blood settle down leaving a clear fluid above known as the *plasma* (Intravascular plasma = Fluid blood − formed elements of blood ; Extravascular plasma = Fluid blood + Anticoagulant − formed elements of blood).

Mechanism of coagulation of blood. The essential processes involved in the coagulation of blood are the (*a*) activation of prothrombin, (*b*) neutralisation of antithrombin and (*c*) the formation of a new substance, the thrombin. Once the thrombin is formed coagulation becomes almost certain.

(A) The prothrombin is activated by—
- (a) Thromboplastins = Lipoproteins.
  - (*i*) Tissue extracts.
  - (*ii*) Platelets.
  - (*iii*) Plasma proteins.
- (b) Ionic calcium.

(B) Neutralisation of Antithrombin Heparin by thromboplastins.
(C) A + B = Thrombin.
(D) Thrombin + Fibrinogen = Fibrin.
(E) Fibrin + corpuscles + platelets = clot.

Coagulation time. It is the time taken by blood to form clot after it (blood) comes out of the vessels. The normal coagulation time varies from 3-8 minutes with an average of 5 minutes. A capillary tube is usually used for this purpose. Blood is collected from a puncture in the finger tip in the capillary tube and by breaking the tube frequently, the time taken to form the clot as solid thread-like structure within the tube is noted. Clinically the coagulation time is of value in assessing a rough estimate about the coagulating mechanism of the blood.

Bleeding time. It is the time required for the stoppage of bleeding after puncture. After a finger puncture by a triangular cutting needle the blood is soaked frequently by a filter paper till the oosing completely stops and the time taken by the process noted. The normal bleeding time is 2½ minutes. Clinically it is of particular value in assessing a rough estimate about the condition of the vessel wall.

Haemolysis. When blood is mixed with distilled water the R.B.Cs. swell up and then they rupture letting out their haemoglobin, and the condition is known as haemolysis. Haemolysis also occurs by toxins, other incompatible substances and when blood of different blood groups is mixed together.

Blood Groups. Various works on blood transfusion have revealed that human blood contains certain substances on the basis of which the whole human

race can be divided into 4 main groups (International classification) with two supplementary blood groups as follows:

Main Groups:	Supplementary blood groups:
Group A.	
Group B.	Rh group.
Group AB.	M and N groups.
Group O.	

It has been found out that the R.B.C. contains some substances of the nature of polysaccharides known as agglutinogen. The blood serum also contains certain substances of the nature of an antibody known as agglutinins. *It is on the presence of the agglutinogen of the R.B.C. that a particular blood group is determined.* Of the main groups three types of agglutinogens namely A, B and AB, are present in the R.B.C. and accordingly the blood groups are A, B and AB types. In group O the R.B.Cs. do not contain any agglutinogen. The agglutinins of the serum are of two types, α and β agglutinins. α Agglutinin is incompatible with A agglutinogen or it is anti-A, while β agglutinin is incompatible with B agglutinogen or Anti-B. It appears then that the AB group cannot have any agglutinin in the serum. Thus it is evident that group O which has no agglutinogen can give blood to any one (universal donor), because its cells have no chance to face agglutinogen—agglutinin re-action. But its serum contains α and β-agglutinins which may react with the cells of the recipient but such chances are remote as the agglutinins concerned undergo high dilution in the recipient's blood.

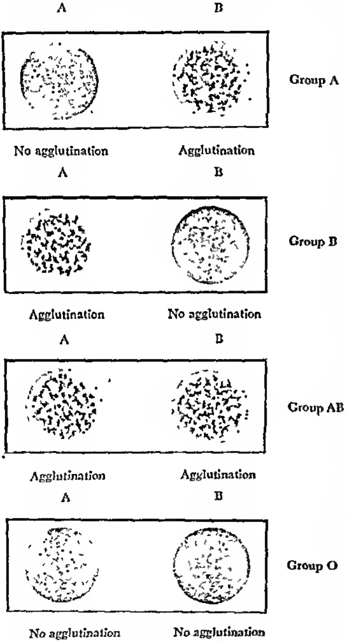


Fig. 77. The agglutinin—agglutinogen re-actions and the determination of blood groups.

The group O, though a universal donor, cannot receive blood from any one except from its own group bacause its agglutinins would react with the cells of the donor. Similarly the AB group having no agglutinin in the serum can receive blood from any one (universal recipient), but the donor's blood may contain some of the agglutinins which may react with the cells of the recipient but serious damages are not likely to occur, as such agglutinins are highly diluted by the recipient's blood.

Determination of the blood groups. Stock agglutinins α and β which are available in the market are put on a slide separately with a mark α and β above the respective agglutinin and a pencil mark is put between them. Then a drop of cell suspension of the unknown blood whose group has to be determined is put side by side with the agglutinin drops and then mixed separately and the reactions noted both macroscopically and microscopically for agglutination or clumping of the cells. Depending on the presence or absence of the agglutinations the group can be determined as shown in diagram No. 77.

Rhesus (Rh) blood groups. Recent investigations have led to the discovery of the existence of such blood groups of extreme clinical importance. As almost all the discoveries make way accidentally through investigations laid out for purposes other than the discovery, so the rhesus blood group came out accidentally while doing experiment on the reaction of the rabbit to the injection of R.B.C. from a rhesus monkey. It has been found out that if a rabbit is injected with R.B.C. from a rhesus monkey it develops an antibody in its blood and subsequently if the serum from such rabbit is added to the R.B.Cs. of the rhesus monkey they are found to agglutinate Later on it has been found out that if such immune serum from the rabbit is added to human blood the R.B.Cs. of large number of people are also found to agglutinate. This led to the discovery that a large number of human blood contains a rhesus factor, that is, an agglutinogen akin to what the R.B.Cs. of the rhesus monkey has. Those who are found to have rhesus factor in their blood are called rhesus positive (Rh +) and those without rhesus factor are called rhesus negative (Rh —).

M and N blood groups. In addition to the above, M and N factors form two supplementary blood groups of no clinical importance but they are of much value in ascertaining the disputed parentage. They are not antigenic to man, that is, they do not develop any agglutinin in the human blood and therefore clinically for purposes of transfusion they are of no importance; but they are antigenic to rabbits, that is, when R.B.C. containing M + N factors are injected to a rabbit, antibodies or agglutinins develop in the rabbit's blood and the serum from such immunised rabbits can be found to agglutinate R.B.Cs. containing M and N factors. A person may have either M factor, N factor or both, that is, MN factors and they are transmitted to the child through genes.

Relations of the blood transfusion to blood groups. The ideal blood transfusion is that between the same groups. In transfusion the main principle of guidance to be considered is the relation between the *donor's R.B.Cs.* and *recipient's serum* because almost all complications are found to occur in adverse relations between the above two factors. Group AB has no agglutinin in their blood and therefore they can receive blood from any group, that is, AB, A, B and O and therefore group AB is taken to be *universal recipient*. Similarly group O has no agglutinogen in their blood and therefore they can give blood to any one and hence this group is taken to be *universal donor*. But group O cannot receive blood from any group except from its own group because according to the principle laid down above we are to consider the donor's R.B.Cs. and the recipient's serum. Here recipient is the group O whose serum contains α and β agglutinins which will agglutinate the R.B.Cs. from group A, B and AB.

Rh or Rhesus blood group and transfusion. If Rh positive blood is transfused to Rh negative group, an antibody (agglutinin) develops in the latter's blood and if the subject receives subsequently Rh positive blood, agglutination of R.B.Cs. occur giving rise to severe haemolytic reactions. During pregnancy if the mother is Rh negative and the child is Rh positive, the mother may develop the antibody (agglutinin) which may pass back to the foetus giving rise to haemolytic disease known as Hydrops foetalis, Icterus gravis neonatorum in the foetus.

In icterus gravis neonatorum there is excessive loss of R.B.Cs. associated with jaundice, and a large number of normoblasts and reticulocytes appears in the blood

due to intense normoblastic reaction of the marrow (Erythroblastosis foetalis). At the same time when the mother, who is harbouring anti-Rh antibody, receives a transfusion of Rh positive blood a severe condition of anaemia may develop in the mother. Therefore, before transfusion, even if we know the blood groups, in order to avoid Rh group incompatibilities it should be the principle to do the test of Direct Matching between the recipient's serum and the donor's R.B.Cs. or to test it for the Rh factor.

CELLULAR ELEMENTS OF BLOOD. The cellular elements of blood consist of coloured corpuscles, R.B.Cs. and colourless corpuscles, W.B.Cs. and the platelets.

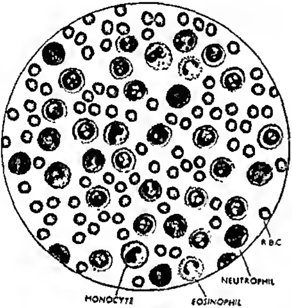


Fig. 78. Cellular elements of blood as seen in a blood film under the microscope.

Red blood corpuscles. These are non-nucleated circular discs, biconcave when seen in profile, having an average diameter of $7{\cdot}21\mu$ with a thickness of 2μ. They number about 5 millions per cu.mm. of blood in the adult male and about 4·5 millions in the adult female. In the newborn they are more numerous and number about 7-8 millions per cu.mm. of blood. During infancy their number is little more than that of the adult.

The colouring matter of the R.B.C. is an iron containing pigment known as *haemoglobin* which is a respiratory pigment capable of carrying CO_2 and O_2. During inspiration the haemoglobin forms a compound with O_2 of the inspired air in the lung as oxyhaemoglobin and carry oxygen to all the tissues of the body. In the tissues after being dissociated with the O_2 they combine with the CO_2 and liberate out the same in the lungs during expiration.

The R.B.Cs. being non-nucleated cells are short-lived and are incapable of cell division and multiplication. The usual span of life of R.B.C. is about 3-4 months. Thus in order to keep up their requisite numbers constant new formation of R.B.Cs. in haemopoietic tissues go on *pari passu* with destruction, and thus their number is kept at a fairly constant level.

Source of origin. The sources of origin of R.B.Cs. vary in life in embryo, and after birth, and the tissue from which they arise in both the cases is known as *haemopoietic tissue.* The distribution of haemopoietic tissues is more extensive in the embryo than in the adult where it is limited mostly to the red marrow.

The haemopoietic tissues or the blood depots in the embryo

(1) *Mesenchymal cells of the extraembryonic mesoderm.* The extraembryonic mesoderm lining the yolk-sac and the chorion forms the earliest sites of blood formation. The "blood islands" formed by the mesenchymal cells on these places form the basis of the blood cells formation.

(2) *Vascular endothelium.* The endothelial lining of certain blood vessels such as caudal aorta, vascular endothelium of liver, spleen and the bone marrow may give origin to the precursors of blood cells by proliferation during the early embryonic life, but later on, they fail to produce such cells as they are transformed into histiocytic lining cells.

(3) *Liver.* The mesenchyme between the liver cells and the vascular endothelium of liver gives rise to histiocytic and haematoblastic cells. The

former is converted into lining histiocytes or Kuffer cells while the latter form erythroblasts and myeloblasts, and when they are ready for circulation, they pass through the thin wall of venous sinuses in the circulation. The haemopoietic activity of liver is transitory and commences from the ninth week of intrauterine life; it begins to decline from the fifth month and soon ceases to continue any further.

(4) *Bone marrow.* Like the liver the bone marrow is also seen to show haemopoietic activities which commence as early as the end of the second month.

(5) *Spleen and Lymph nodes.* The reticular cells of the white and the red pulp of the spleen and of lymph nodes may give rise to all varieties of blood cells.

Haemopoietic tissues of the adult. In adult the haemopoietic tissue is mostly confined to *red marrow of the vertebrae, ribs, sternum, cranial* and *pelvic bones.* At puberty the red marrow may be found in all spongy bones including the ends of all long bones.

With advancing age the field of haemopoietic tissues becomes limited and the red marrow is replaced by yellow marrow in the bones of the lower part of the vertebral column and in the spongy bones at the distal ends of long bones. But in the *sternum* the *red marrow persists throughout life* and for this *sternal puncture* is the usual method for collecting sample of red marrow for clinical examinations. Under conditions of stress and strain the liver and the spleen may also take up haemopoietic activities.

Structure of red marrow. The red marrow consists of a net-work of reticular tissue in the meshes of which there are numerous cells of different types, and blood vessels which ramify and anastomose each other. The following are the different types of cells found in the red marrow:

(1) Myelocytes or marrow cells.
(2) White blood corpuscles.
  (*a*) Neutrophilic leucocyte.
  (*b*) Eosinophilic leucocyte.
  (*c*) Basophilic leucocyte.
  (*d*) Monocytes.
  (*e*) Lymphocytes.
(3) Red blood corpucles.
(4) Erythroblasts.
(5) Giant cells.
(6) A few fat cells.

Structure of yellow marrow. It consists mostly of fat cells and a few blood forming cells.

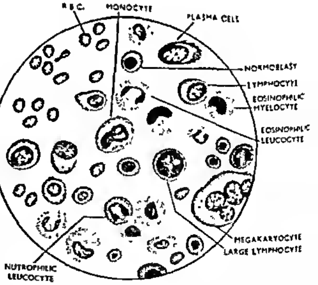


Fig. 79. The cells of red bone marrow.

Stages in the development of R.B.C. It is most unhappy that the nomenclature for the cells in gradual development has not been standardised even now and hence a great deal of inconvenience is experienced in using their nomenclature. In order to avoid confusion I have followed Sabin and have used the nomenclature given by him. According to Sabin from the parent endothelial cell the R.B.Cs. pass through the following stages of development:

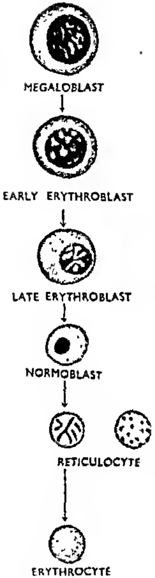


Fig. 80. Stages of development of R.B.C.

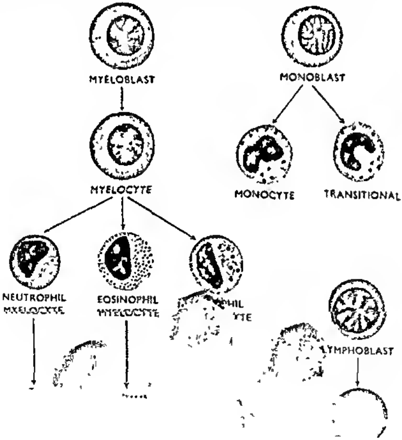
1. *Megaloblast*	Large cell with a diameter varying from 15-20μ; cytoplasm stains deep violet-blue having a crescentic pale staining area; Nucleus *is large and round; is devoid of Hmg.* Mitotic figure may be found.
2. *Early Erythroblast*	The cell is comparatively smaller than the above; cytoplasm same as above; Nuclei have disappeared, the chromatin net-work shows signs of condensation at places. Mitotic figure present. No Hmg.
3. *Late Erythroblast*	Same as above except that the cell is smaller and the chromatin network shows signs of more condensation. Hmg. begins to appear.
4. *Normoblast*	The cell is much smaller and varies from 7-10μ in diameter, the nucleus is cart-wheel in appearance due to rearrangement of the chromatins. No sign of mitosis; Hmg. content is maximum. Cytoplasm shows eosinophilic reaction.
5. *Reticulocyte*	The cytoplasm is reticular as shown by vital staining. No nucleus.
6. *Erythrocyte*	Non-nucleated biconcave disc full of Hmg. having an average diameter of 7·21μ.

The white blood corpuscles. Compared to R.B.Cs. these are colourless cells and hence called "white blood corpuscles". Depending on the staining reaction they can be divided into two main sub-groups, *granulocytes* and *agranulocytes*. The granulocytes contain numerous granules in their cytoplasm which show characteristic staining affinities and depending on this staining behavior they are further subdivided into *eosinophil, basophil* and *neutrophil*. The granules of the eosinophil cells show staining affinities for acid dyes (cabol fuchin) the basophil for basic dyes (Gentian Violet) whereas the neutrophil cells show staining affinities for neutral dyes (Leishmans stain). The agranulocytes do not contain any granule in their cytoplasm and they are further subdivided into *lymphocytes* and *monocytes*. Lymphocytes can be further divided into *large* and *small lymphocytes*. The following is a table showing the subdivisions of the white blood corpuscles or the leucocytes:

White blood corpuscles or Leucocytes

- Granulocytes
  - Basophil
  - Neutrophil
- Agranulocytes
  - Lymphocytes
    - Large lymphocytes
    - Small lymphocytes
  - Monocytes

Development of white blood corpuscles or Leucocytes. *Granulocytes*—The granulocytes develop extravascularly (outside the blood vessels) both in embryo and in extrauterine life (after birth) and after their extravascular origin they migrate into the blood vessels. *In embryo* they develop from the mesoderm whereas in *extrauterine* life they develop from the red bone marrow.



The *agranulocytes* develop usually from the lymphoid tissue of the body but they may also arise from the red bone marrow although to a very limited extent.

Stages in the development of granulocytes. The parent cell for the granulocytes is the reticular cell of the bone marrow which lies outside the sinusoidal blood vessels in between the fat cells. The reticular cells multiply by mitotic cell division and form *primitive white blood corpuscles* which gradually develop into myeloblast, premyelocyte or myelocyte A, myelocyte proper or myelocyte B, metamyelocyte or myelocyte C or leucocyte. The following are the individual characteristics as they acquire in their stagewise development:

The stem cell or the reticular cell. It is a large cell with irregular outline and branching processes. The cytoplasm is agranular which stains with basic dyes.

Myeloblast. It arises from the undifferentiated agranular stem cell of red bone marrow and resembles a lymphocyte in appearance in having a basophilic nongranular cytoplasm.

Nucleus. The nucleus is usually large and the *nuclear membrane* is exceedingly thin, smooth and of even outline and there is no condensation of chromatin in its inner zone as is found in the lymphocytes. The chromatins are evenly distributed throughout the nucleus with some condensation around the nucleoli and do not form any clumping masses. The nucleoli are multiple and usually vary from 2-4 in number.

The **cytoplasm** is reticular, spongy or foamy in character in contrast to homogeneous cytoplasm of the lymphocytes.

Biochemical character. The cell presents a proteolytic ferment and shows oxidase and peroxidase reactions.

Premyelocyte or Myelocyte A. The cytoplasm contains granules which are basophilic. The nucleus is more basophilic and there is no nucleolus. Chromatins are coarser.

Myelocyte proper. Its cytoplasm contains more granules and is intermediate between premyelocyte and metamyelocyte in structure.

Metamyelocyte or Myelocyte C or Leucocyte. Cytoplasm contains numerous granules. The nucleus is lobulated.

Development of agranulocytes. *Lymphocytes.* The lymphocytes develop from the lymphatic tissues of the body. The reticular cells at the germinal centre of the lymph node proliferate and differentiate into a large cell, the lymphoblast which divides to form a large and a small cell. The large cell forms the large lymphocyte while the latter changes into small lymphocyte. A few lymphocytes may develop within the bone marrow from the reticular cells in the same way and may gain access directly into the blood vessels. The lymphocytes originating from the lymph node gain access into the blood vessels indirectly via thoracic duct.

Monocytes. The monocytes have a separate line of origin from the lymph nodes and to some extent from the red bone marrow and their stages of development are stem cell, monoblast, monocyte.

Macrophage system or the Histiocytes or Reticulo-endothelial system

Metschnikoff used to call the blood leucocytes as "microphages" as they had the power to engulf foreign bodies, micro-organisms, cellular debris, etc. and in contrast to microphages, he gave the name "macrophages" to some of the connective tissue cells, which he found to possess the same type of functions but they were larger and at the same time their power of ingesting foreign bodies etc. were found to be more pronounced.

Various other workers engaged in discovering macrophage system of cells confirmed about their identity but named them differently in their own way of thinking. Thus the macrophages of Metschnikoff also go by the name "clasmatocytes" 1

Ranvier, "adventitial cells" by Marchand and "resting wandering cells" by Maximow. Subsequently it has been observed that there are several cell types widely distributed in our body whose functions are similar to the macrophages or the histiocytes originally discovered, and all these cells go by the common name macrophages or the macrophage system of cells or the reticulo-endothelial system of cells.

It has been found out that when vital or supravital stains are injected intravenously to a living animal the stains are taken up selectively by the macrophage system of cells and on the basis of this observation their distribution in the body has been located. Although, all of them behave functionally almost in the same way, their physical characters vary considerably according to their location in the tissues.[1] The following cell types can be identified according to their distribution in the tissues or in other words the macrophage system of cells consists of the following cell types:

Macrophage system or the Reticulo-endothelial system

Fixed Histiocytes

(1) Resting wandering cells of common connective tissue and the serous membranes, particularly the greater omentum.

(2) Reticular cells of the lymphoid tissue, red pulp of the spleen and the myeloid tissue of the bone marrow.

(3) The squamous cells lining the venous sinuses of the spleen, bone marrow and the lymph sinuses.

(4) Phagocytic cells of the vascular endothelium of the sinusoidal blood vessels of the adrenal and the pituitary glands (Ant. lobe)

(5) Phagocytic stellate cells of Von Kupffer in the sinusoids of the liver.

(6) The microglia of the C.N.S.

Wandering Histiocytes

Fixed Histiocytes when acquire wandering activity

Blood Histiocyte

Fixed Histiocytes gaining access to the circulation

Monocytes of blood

Functions of the Macrophages

(1) Phagocytosis is the main function of the macrophages.
(2) Colloid substances are stored by the macrophages for their ultimate disposal.
(3) They are concerned in the metabolism of fats, lipoids, haemoglobin and iron.
(4) They are also concerned in the destruction of R.B.Cs., particularly in the spleen.
(5) They produce bile pigments, particularly in the liver.
(6) They are of great concern in the repair of tissues.
(7) They are also known to produce enzymes and antibodies.

THE MUSCULAR TISSUE

The most important sign of life is "movement" which sharply distinguishes animates from the inanimates. In living animals all protoplasmic bodies react to stimulation by showing movements and certain tissues such as leucocytes and the ciliated epithelium possess inherent properties to move. In higher animals the muscular tissue is a specially designed component possessing wide range of movement. The movement occurs by alternate contraction and relaxation and thus *contractility is the inherent property of all types of muscular tissues.*

Characteristic features. The muscular tissue is characterised by the presence of muscle fibres which are arranged in bundles or fasciculi and the muscle fibres in each fasciculus run parallel to one another. An individual muscle fibre is surrounded by a delicate layer of loose areolar tissue known as the *endomysium*. A group of muscle fibres is arranged into a bundle to form individual *muscular fasciculus* which is surrounded by another denser layer of areolar membrane known as the *perimysium*. Ultimately the muscular fasciculi are bound and ensheathed together by a common areolar membrane known as the *epimysium* to form the individual muscle; the epimysium becomes thickned to intervene between two groups of muscles to form the *intermuscular septum*.

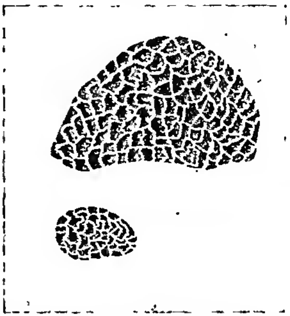


Fig 82. The figure above is a transverse section of muscle showing muscular fasciculi. The figure below is a transverse section of an individual fasciculus showing individual muscle fibre with it surrounding endomysium

Development. All muscular tissues develop from the mesoderm except the arrector pilorum of the skin and the ciliary muscles of the eye which are of ectodermal origin.

Varieties of the muscular tissue. Structurally the muscular tissue can be divided into *striated, non-striated* or *plain* or *smooth,* and *cardiac muscles.* Functionally, it can be divided into *voluntary* and *involuntary muscles* and developmentally, into *somatic* and *visceral muscles.* The striated muscles fall under voluntary group whereas the cardiac and the non-striated muscles fall under involuntary group.

Histological structure of Striated or Somatic or voluntary muscle. Each somatic muscle fibre varies in length from 1 mm. to 130 mm. and in thickness, from 10 to 100μ.

Each muscle fibre consists of an outer membranous envelope known as the *sarcolemma* contained within which is a mass of protoplasm known as the *sarcoplasm*. Within the sarcoplasm, situated just beneath the sarcolemma, is the nucleus of the cell (nucleus at the periphery) which is oval in shape. The sarcoplasm also contains a number of fine, delicate fibrils known as the *myofibrils*. The myofibrils run parallel to one another and may be arranged either in bundles, being separated from one another by some amount of sarcoplasm, or they are found closely packed together within the muscle fibre. The myofibrils are alternatively called *sarcostyles*, and in longitudinal section each myofibril is seen to show alternate *light* and *dark segments* at regular intervals and these segments occupy the same line in all the myofibrils, so that, when viewed together, they present a striated appearance and hence a somatic muscle is alternatively called a *striated muscle.* Running across the centre of each dark segment is a fine light line known as *Hensens' line.* Similarly running across the light segment is a dark line known as the *Krauses line or membrane.*

Each dark segment is anisotropic, that is, it is doubly refractile and appears dark by transmitted light and is known as "A" disc. Each light segment is singly refractile or isotropic and appears clear by transmitted light and is known as "I" disc. "A" discs, that is, dark segments, stain deeply with haematoxylin while the " discs remain uncoloured by haematoxylin. During contraction of a muscle, as se

under the electron microscope, the "A" discs shorten while the "I" discs lengthen due to unfolding of myosin filaments of which it is composed of. The myosin filaments in "A" discs run in parallel with the length of the myofibril.

Fig 83 Structure of a Somatic Myofibril.

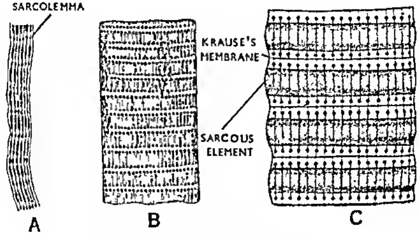


Fig 84. A—showing alternate white and dark striations.
B—more magnified view—showing nuclei.
C—still more magnified.

Involuntary or Visceral muscle. Involuntary or visceral muscles are widely distributed in the body and they act independently without having any volitional control. They are found in the walls of the hollow viscera, blood vessels, hollow ducts of the exocrine glands, and in the sweat glands, within the fibrous capsule of the spleen and other lymph glands, in the Iris and ciliary body and in the walls of the terminal bronchiole (bronchial muscle). The levator palpebrae superioris is a mixed muscle containing both somatic and visceral muscle fibres; the Muller's muscle is also made up of visceral muscle fibres.

Minute or Histological Structure. Histologically the visceral muscle consists of elongated fusiform cells with a centrally placed oval nucleus. The sarcoplasm contains myofibrillae but they do not present transverse striation and hence alternatively called smooth muscle. There is no sarcolemma and the cell wall being formed by a delicate membrane of reticular tissue.

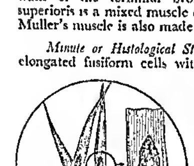


Fig. 85. Involuntary muscle fibre.

There is wide range of variations in the mode of arrangement of the visceral muscle fibres, thus in the walls of the intestine they are arranged in layers, in the urinary bladder the fibres interlace with one another, in the skin, they are scattered either in groups, or singly, and in some places they are irregularly arranged or they form an incomplete ring of muscular tissue. Like somatic muscles they are also invested by connective tissue layer which contain blood vessels, nerves and lymphatics.

Cardiac Muscle. The cardiac muscle forms a group by itself and is confined to the musculature of the heart. Although in cardiac muscle there is amalgamation of some features of both somatic and visceral muscles (presents striations like somatic muscle and is involuntary in action like visceral muscle) yet its special feature branching fibres which anastomose with one another freely, distinguishes it at once from both the somatic and the visceral muscles.

DIFFERENCE BETWEEN SOMATIC AND VISCERAL MUSCLES

	Somatic muscle	Visceral muscle
Development	Develops from somatic paraxial mesoderm.	Develops from splanchnic mesoderm.
Structure	Fibres are transversely striated. Nucleus peripherally placed. Presence of sarcolemma sheath.	Fibres are non-straited. Nucleus centrally placed. No sarcolemma sheath.
Nerve supply	Supplied by somatic nerves.	Supplied by autonomic nerves.
Tonicity and contractility	Tonicity and contractility of the muscle are dependent on its nerve supply. Contracts quickly but becomes less sustained. Fatigue comes earlier.	The muscle can contact spontaneously without any nervous influence. Contracts slowly and becomes more sustained. Not easily fatigued.

Minute Anatomy or Histological Structure. The cardiac muscle fibres consist of quadrangular forked cells with central nuclei ; the cells branch out freely to anastomose with their fellows, cell to cell and branch to branch. Thus a cellular syncytium is formed which makes the basis for the contraction wave to move from one part of the heart to the other. The sarcolemma is too delicate to be demonstrated easily and intervening between the fibres is a very thin layer of loose connective tissue which is rich in blood supply. The sarcoplasm is more granular and contains myofibrillae towards the periphery of the cell whereas the nuclei are laced centrally either in rows or in close packing. Like omatic muscle the myofibrillae are transversely striated ut they look less prominent because they are embedded in the granular sarcoplasm. In addition, the muscle fibres present longitudinal striations also. At certain intervals each of the muscle fibre is marked transversely by darkly staining band known as the *intercalated disc.* The intercalated discs are not straight and transverse but they consist of short transverse markings connected together in steps. The presence of the intercalated discs is another most prominent distinguishing feature for the cardiac muscle.

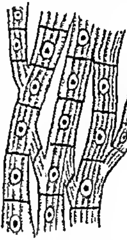


Fig. 86. Structure of cardiac muscle.

The specialised tissues of the cardiac musculature. The sino-auricular node (S.A. node), the auriculo-ventricular node (A.V. node), the bundle of His and its ramifications into Purkinje fibres constitute the specialized tissues of the heart. Usually S.A. node, and exceptionally the A.V. node is responsible for the origin of the cardiac rhythm whereas the rest of the specialised muscular tissues are responsible for the propagation of the contraction wave from the auricles to the ventricles.

The S.A. node. The S.A. node is situated on the inner wall of the right atrium to the left of the upper end of the crista terminalis and on the anterior aspect of the opening of the superior vena cava, and extends downwards for about 2 c.m. ($\frac{3}{4}$"). It consists of a specialised neuromuscular tissue which is embryonic in type and contains amongst the plexiform network of muscle fibres the nerve cells (ganglion cells) and fibres, all of which are intermingled in a base of connective tissue element. The tissue is rich in vascular supply and in its glycogen content.

The A.V. node. Microscopically the A. V. node consists of almost the same structures that are found in the S.A. node. It is situated within the right atrium at the lower part of the interatrial septum in between the opening of the inferior vena cava and the right atrioventricular orifice.

Bundle of His. For course and distribution see Chapter on heart.

Purkinje Fibres. The Purkinje fibres form the terminal arborising fibres of the bundle of His which consists of cells which are comparatively larger with large pale nuclei. Nerve cells and fibres are also seen scattered amongst them.

DIFFERENCE BETWEEN CARDIAC AND VOLUNTARY MUSCLES

	Cardiac muscle	Voluntary muscle
Nucleus	Nuclei are centrally placed within the fibre	Nuclei are placed peripherally under the sarcolemma sheath.
Transverse striation	Transverse striations are ill-defined	Transverse striations are well-defined.
Fibres	Individual fibre branches and anastomoses with one another, "quadrangular forked fibres".	The fibres do not branch at all.
Sarcolemma	Ill-defined	Well-defined.
Intercalated discs	They form a characteristic feature of the cardiac muscle.	They are not found in the somatic or Voluntary muscles.

THE NERVOUS TISSUE

General introduction. The nervous tissue is a highly specialised tissue which is of ectodermal origin and differentiates from the medullary or the neural epithelium. This tissue, being a highly differentiated one, is incapable of further re- or de-differentiation and therefore, for its integration into the body, the nature has provided a sound architecture for its protection. The brain and the spinal cord, the latter being the direct tubular continuation of the former, which form the main bulk of the nervous tissue, are contained in the rigid cranial cavity and the vertebral canal respectively. Thus they are protected from all extraneous influences except through the linking peripheral nerves. Moreover, the tough duramatter, the arachnoid and the piamatter form three close envelopes from without inwards around the brain and the spinal cord. Having been thus secured in position they establish connection with the peripherally disposed structures through nerves.

The behaviour of nervous tissue. The inherent quality of the nerve tissue is to receive stimuli from outside, to initiate impulse and to conduct the same to different effector organs in our body which react differently to give rise to a response.

Characteristic features. *Macroscopically* the nervous tissue consists of grey and white matters. *Microscopically* the grey matter consists of nerve cells of varying shape and size ; each nerve cell consists of a cell body with branching processes of various patterns, of which, one is an axon and the others are dendrons. *Absence of centrosome and the presence of Nissl's granules and neurofibrils are special features of nerve cells.*

Development of the nerve cells. It has already been mentioned that the nerve cells are derived from the ectoderm except the microglia cells which are derived from the mesoderm. Given below in a tabular form are the stages of development of the nerve cells :

Medullary epithelium or the neural epithelium

- Primitive spongioblast
  - Ependyma
  - Spongioblast
- Spongioblast
- Medulloblast
  - Spongioblast
  - Neuroblast
    - Neuron
- Neuroblast
  - Neuron

- Astroblast
  - Protoplasmic Astrocyte
  - Fibrous Astrocyte
- Oligodendroblast
  - Oligodendrocyte

A neuron or a nerve unit. A nerve cell consists of a cell body known as the cyton, and short and long processes known as the dendron and the axon respectively. *The nerve cell receives impulses through its dendron and transmits the same through its axon to other cells.* The axon of one cell arborises round the dendrons or the cell body of another in which the former makes a contact with the latter and the connection between the two is known as a *synapse.* Thus the nerve impulse from one cell is propagated to the another through its synaptic connection and finally the impulse is carried to the effector organ or the higher nerve centre. It then appears that the nervous pathway is made up of a series of inter-linking nerve cells through which the nerve impulse is propagated. The component unit of a nervous pathway formed by a single nerve cell with its processes is called a *neuron* or a *nerve unit.*

DIFFERENCES BETWEEN AN AXON AND A DENDRON

	Axons	Dendrons
Length	Usually long but they may be short as well.	Usually short but they may be long as well.
Thickness	Uniform thickness.	They taper as they branch.
Nature of division	They divide mostly at right angle close to their termination.	They divide at acute angle.
Number in each cell	There is only one axon in a neuron	They are usually multiple.
Structure	Structurally different from the cell.	Structurally same as the cell.
External appearance	Smooth.	Rough.
Nature of conduction	Conduct away from the cell body or the cyton.	Conduct into the cell body or the cyton.

Classification of neurons. *Functionally* neurons may be classified into *motor neurons, sensory neurons* and *intercalated neurons. Structurally,* depending on the nature of the axons, the neurons are classified into *Golgi's type I* and *Golgi's type II* neurons, while *according to poles* the neurons are subdivided into *unipolar, bipolar* and *multipolar types.* The different types of neurons are tabulated as below:

Neuron

- Functionally
  - (a) Motor Neuron { Upper motor, Lower motor
  - (b) Sensory neuron
  - (c) Intercalated neuron
- Structurally
  - (a) Golgi's type I
  - (b) Golgi's type II
- According to poles
  - (a) Unipolar
  - (b) Bipolar
  - (c) Multipolar

Motor or efferent neuron. These neurons carry motor or volitional impulses from the brain and the spinal cord to the peripheral effector organs such as muscles, secreting glands, vessels etc. They consist of cells whose dendrons are numerous, short and branching whereas their axons are long, sometimes as long as two feet or more, and they do not usually branch except at their point of arborisation.

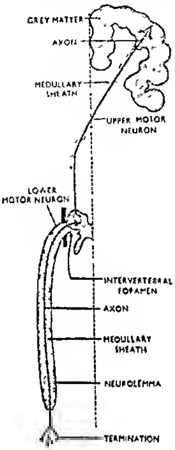


Fig. 87. Diagram showing upper and lower Motor neurons.

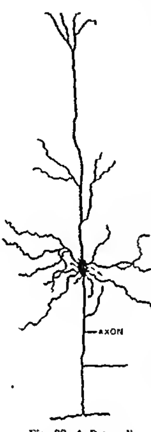


Fig. 88. A Betz cell.

Upper Motor Neuron. The upper motor neuron is the first neuron in the motor pathway which has its synaptic termination at the lower motor neuron. Betz cells or pyramidal cells form the main bulk of the upper motor neurons, although some other cortical and subcortical cells (Extrapyramidal tract fibres) may be included in it.

Lower Motor Neuron. The lower motor neuron is the last neuron in the motor pathway the axon of which makes its connection with the effector organs (muscles, glands, etc.) They consist of motor cells of the ventral columns of the spinal cord and the nuclei of the brain stem.

Upper and lower motor type of lesions. Injury or diseases affecting the motor pathway may involve either the upper or the lower motor neurons. Clinical signs and symptoms vary according to the seat of lesion involving either the upper or the lower motor neurons and they are compared below in a tabular form :

	Upper motor neuron type of lesion	Lower motor neuron type of lesion
Type of paralysis	Paralysis with rigidity "clasp-knife" type.	Paralysis with flaccidity.
Tone of muscles	Exaggerated (Hypertonic).	Diminished (Hypotonic).
Wasting of muscles	Slight wasting due to disuse.	Pronounced wasting.
Trophic changes	No change in the skin	The skin may be cold, shiny or bluish in colour. Trophic ulcers may occur.
Deep reflexes or Tendon reflexes	Exaggerated. Clonus may be present	Diminished or absent.
Superficial reflexes	Diminished, modified or absent.	No change.
Electrical reactions	No change.	Reaction of degeneration present.

Sensory or afferent neuron. These neurons carry sensory impulses from the periphery to the centre, that is, the brain and the spinal cord. Whereas in the motor neuron the axon is the longest process, in sensory neuron the axon is as short as the dendrons of the motor neuron and its dendrons are the longest processes. The cells of the sensory neurons are situated peripherally and they receive impulses from the peripheral areas through their long dendrons and transmit the same to the higher centre through their axons. *The cells of the* posterior root ganglion of the spinal nerves are sensory neurons.

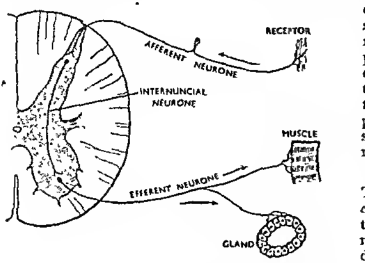


Fig. 89. Reflex arc showing afferent, efferent and intercalated neurons.

Intercalated neuron. These are small neurons which *effect synaptic connection be*tween efferent and afferent neurons. Both the axons and dendrons of these cells are almost equal in size and it is difficult to distinguish axon from the dendron anatomically, though they can be easily recognised physiologically by different physiological methods.

Golgi's type I. The neurons in this group are characterised by long axis cylinder processes by means of which they establish connection with remotely placed organs or cells. The cell body of these neurons are of considerable size and contains sufficient amount of cytoplasm.

Golgi's type II. The cells of this group are very small with short axons and are present in the layer IV of the cerebral cortex. Due to their short axons they never extend beyond the cell layers of the cerebral cortex and they usually establish connection between the neurons of the adjacent layers. The intercalated neuron of the spinal cord also falls under Golgi's type II.

Unipolar cells. These cells have only one pole from which both the axon and the dendrons arise, the pole splitting dicrotomously into axon and dendron. They are not usually found in the adult human body but they are abundantly present in early foetal life when the neuroblasts, the precussors of the nerve cells, at some stage of their development, become unipolar. *The embryonic type of* unipolar cells are found only in the sensory nucleus (mesencephalic nucleus) of the fifth cranial nerve in the adult human body.

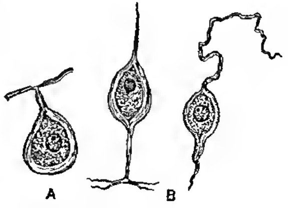


Fig. 90. A—Unipolar cell. B—Bipolar cells.

Bipolar cells. The cells are fusiform in shape and have two poles, one giving origin to the axon and the other to the dendron. In the adult human body they are found in the cochlear and vestibular ganglion of the auditory nerve. The cells of the posterior root ganglion are also of bipolar type but here because the two poles have converged together the cells resemble like the unipolar type with single pole bifurcating into two

processes, short and long, the short process being the axon and the long process, the dendron.

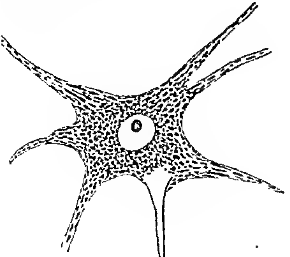


Fig. 91 A multipolar cell.

Multipolar cells. These cells have multiple poles with processes, of which, one is a axon and all others are dendrons. They are widely distributed in the cortex of the cerebrum, cerebellum and the spinal cord.

Synapse. The synapse (GK. Syn=together; aptein=clasp) or the relay between two neurons, is the junction in the pathway of a nervous impulse where two neurons meet together and the impulse from one flows out to the other just as the power or electricity moves between two wires (transmission by electrical potential) or it is conveyed to the other by a chemical mediator (Adrenaline or acetyl choline) or a transformer.

As the transneuronal junction is a overlapping link and not a structural continuity the nerve impulse from one in its passage to the other is faced with a handicap and so its speed is slowed down. Therefore the synaptic mechanism is a sort of resistance in the pathway of the nervous impulse comparable to the resistance put in the electrical pathway (think of regulator of a fan). As a resistance in the electrical pathway is a device for variable responses so the nature has provided synapses in the nervous pathway to have variable responses from the effector organs. Roughly about ·5 sigma (one sigma is equal to 1/1000 part of a second) or more is taken up by an impulse to cross a synapse.

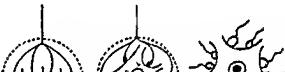


Fig. 92. A—Synapse formed between axon and dendrite Terminal points of axon showing synaptic knobs.
B—Synapse between axon of one and dendrites and cell body of the other.
C—Synaptic knobs.

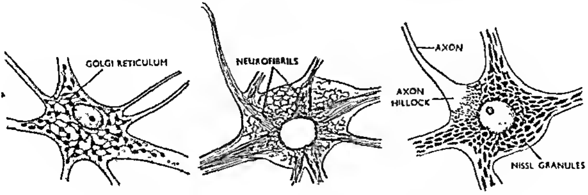
At a synapse the nerve impulse is conducted to one direction only, that is, from the axon of one to the dendrons or the cell body of the other, or in other words it is a one-way traffic for the impulse at a synapse. This behaviour of selective transmission is referred to as the *Law of Dynamic Polarity*.

Internal structure of a nerve cell. The most important characteristics of the internal structure of a nerve cell which make them to differ from other types of cells are the *absence of centrosome* and the *presence of the Nissl bodies and the neurofibrils*. Besides these it contains all other elements that are found in an ordinary cell, that is nucleus, mitochondria, Golgi apparatus and pigments, and as such they do not deserve special mention.

Centrosome. This is conspicuously absent in a fully developed nerve cell and this is the reason why a nerve cell once injured is incapable of further regeneration by cell division and usually succumbs to the effect of the injury.

Neurofibrils. The presence of neurofibrils forms another important feature. These fibrillary structures are not only present within the cell body but they also flow out into the different processes of the nerve cell. Ordinarily they are not visible

under the microscope but when treated with silver salts they are made visible under the microscope. Nothing definite is known about these structures but it is believed that their presence within the nerve cell is in someway related to the cell activity.



A B C
Fig. 93. A—shows superficial reticulum of *Golgi* ; B—shows neurofibrils ; C—shows Nissl Granules.

Nissl bodies. Named after the discoverer Nissl bodies form small, angular, basic staining granules within the nerve cell and are found seattered throughout the cell except close to the origin of the axis cylinder process. They also flow out into the dendrons but not to the axons. The point of origin of the axon where the Nissl bodies are absent is called the *axon hillock*. The absence of the Nissl bodies from the axon forms a characteristic feature by which axon can be distinguished from the dendrons, particularly in case of intercalated neurons where axons are much smaller. Chemically the Nissl bodies are a compound of nucleoprotein with organic iron.

Fig. 94
A somatic nerve.

Nerve ganglion. Any collection of nerve cells in the course of a nerve is known as the *ganglion* which acts as a cell-station in the nervous pathway. Those found along the sympathetic and parasympathetic nerves are known as the *sympathetic* and *parasympathetic ganglion* respectively.

The nerve or the nerve fibre. The nerves in the human body may be likened to the wirings in a machinary. Just as the power or the electricity from some generator dominates in the run of a machine through the wirings so the nerve impulse from the central nervous system (Generator of nerve impulses) controlls the body mechanics of the human body through the nerves. They are white glistening, thread-like structures which are widely distributed in the body and are linked to the central nervous system either directly or indirectly through cell-stations.

Classification of nerves. Structurally nerves are divided into *myelinated* and *unmyelinated* nerves while functionally they are classified as under:

- Nerves
  - Motor or Efferent
    - Cerebral
    - Spinal
  - Sensory or Afferent
    - Nerve of general sensibility
    - Nerve of special senses
  - Autonomic nerves
    - Sympathetic

Motor nerves. The motor nerves in general carry motor or volitional impulses from the motor area of the brain and propagate it into muscle or muscles concerned so as to execute a particular type of movement.

Sensory nerves. The sensory nerves carry different types of sensory impulses from the periphery and having passed through different cell-stations are finally distributed to the sensory area of the brain. Nerves of general sensibility carry pain, heat, touch, cold, pressure, pain and deep sensations whereas nerves of special senses convey to the brain different kinds of special senses such as taste, smell, hearing and vision

Autonomic nerves. The actions of these nerves are not under the volitional control and as such they are automatic in action. They consist of sympathetic and parasympathetic nerves. The functions of sympathetic and parasympathetic nerves are peculiar in that both are automatic in action but the action of one is diametrically opposite to the other, as for example, the sympathetic nerves for the heart cause it to contract but the parasympathetic nerves cause it to relax. Of the autonomic nerves those which cause contraction is known as the *effector or accelatory nerves* and those cause relaxation are known as *inhibitory nerves*. The same nerve may be accelatory in action in one viscera but inhibitory for the other (Vagus nerve is inhibitory for the heart but accelatory for the intestines).

Structure of a myelinated or medullated nerve. *Gross structure*—A nerve is a bundle of nerve fibres which is surrounded by an areolar tubular sheath known as the *perineurium*. From the perineurium areolar processes pass within the nerve so as to enclose individual nerve fibre and this tubular sheath which encloses individual nerve fibre is known as the *endoneurium*. In large nerve trunks numerous nerve fasciculi are held together by a common areolar investment known as the *epineurium*.

Minute structure. An individual nerve fibre consists of a central thread-like process known as the *axis cylinder process* which is composed of a number of fibrillary structure known as the *neurofibrils*. Surrounding the axis cylinder is a tubular sheath of thicker consistency known as the *myelin sheath*; surrounding the myelin sheath is another sheath of thinner consistency known as the *neurilemma sheath*. Thus the nerve fibre may be likened to a wooden pencil, the axis cylinder being the lead, the myelin sheath, the wooden shaft, and the neurilemma sheath, the enamel coating of the pencil.

Myelin sheath. It is a highly refractile, whitish, double contour sheath which closely invests the axis cylinder process and is responsible to give the white colour to a nerve. It does not form a continuous sheath but at places at regular intervals it is deficient where the neurilemma sheath dips in to form a close investment around the axis cylinder process. The point where the myelin sheath is deficient is called the *node of Ranvier* and the segment of the nerve in between two nodes of Ranvier is called an *internode*.

Neurilemma Sheath or the Sheath of Schwann. It is an unbroken, nucleated, tubular sheath which lies superficial to the myelin sheath. *It is of ectodermal origin and is derived from the neural crest.* It consists of schwann cells which contain flattened, elongated nuclei and its cytoplasm is modified to be thinned out and elongated to form a membranous investment over the myelin sheath of the nerve. Usually one nucleus is found over each internode. In case of injury to a nerve if the neurilemma sheath remains intact, regeneration of the nerve takes place with the help of this sheath. Thus the presence of neurilemma sheath is essential for the regeneration of a nerve. The *optic nerve*, and *the nerves and nerve tracts within the central nervous system have no neurilemma sheath* and consequently these structures, (optic nerve, and the nerves and nerve tracts within the brain and spinal cord) when injured, fail to regenerate.

Amyelinate nerves or non-medullated nerves. These nerves are called amyelinated nerves because they have no myelin sheath. All post-ganglionic fibres are amyelinate fibres; besides these they are also found intermingled with the peripheral nerves.

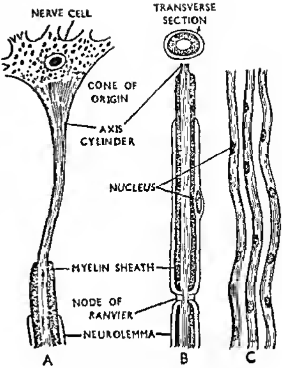


Fig. 95. A & B—Medullated Nerves. C—Non-Medullated Nerves.

The neuron theory. It was in 1891 when Waldeyer first postulated the doctrine about a neuron which is still in vogue and usually goes by the name "neuron theory". In this theory Waldeyer described in a simpler way about the nature of a neuron in respect of its structure, function, origin, effects of injury and conductivity. The following are the observations on the basis of which the neuron theory has been established :

1. A neuron is the smallest unit of a nervous pathway and consists of a nerve cell with its processes. It is a complete anatomical unit which together with other neurons forms a neuron chain by contiguity (synapses) and not by continuity.
2. Functionally it forms the smallest segment of the functional chain of a neuron pathway (Functional unit).
3. A neuron is the last descendant of the embryonic neuroblast (Genetic Unit).
4. When the axon of a neuron is divided the cell undergoes chromatolysis.

Effect of injury to a nerve. When an axon is severed, changes quickly follow n both the segments on either side of the division. In adverse circumstances both ne cell body together with the proximal stump attached to it as well as the distal egment succumb to the effect of the injury and regeneration does not occur. In avourable circumstances the cell survives and regenerative processes soon ensue fter a initial degenerative phase. Thus the effect of injury to a nerve may be iscussed as under :

(1) ***In adverse circumstances.*** The cell dies and both its segments disappear.

(2) **In favourable circumstances.** The cell survives the effects of initial trauma and after a brief period of degenerative changes regeneration soon begins. The initial degenerative changes that affect the proximal segment is known as "*retrograde degeneration*" whereas that affects the distal segment is called "*Wallerian Degeneration*".

Degenerative changes. *Retrograde degeneration.* Soon after the injury degenerative changes affect both the cell body as well as the axon still attached to the cell body. The cell body shows signs of disintegration of the Nissl bodies (chromatolysis) which at first become unstainable and ultimately disappear. There is shrinkage of the nucleus which is displaced towards the cell margin. The axon still connected with the cell body also shows signs of degeneration which, in favourable cases, extend towards the cell body from the point of division up to the first node of Ranvier and then, regeneration follows quickly. [In adverse cases when the cell body succumbs to the effects of the injury during the stage of chromatolysis as a result of violent reaction the whole of the proximal segment of the axon also undergoes Wallerian degeneration and quickly disappears and consequently regeneration cannot occur in these cases].

Wallerian degeneration. The degenerative changes that affect the distal segment is usually referred to as *Wallerian degeneration* because it was Waller, a physiologist, who first described the changes during the last century.

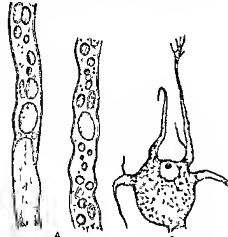


Fig 96 A—showing myelin droplets as degeneration proceeds B—cell undergoing chromatolysis nucleus has become eccentric

In Wallerian degeneration the neurofibrils of the divided axon at first become tortuous or wavy and then they break into numerous segments. Subsequently the myelin sheath swells up and is transformed into a chain of lipoid droplets. Finally, within two or three weeks following the injury the debris resulting out of the degenerative processes are removed by the phagocytes and nothing remains except the neurilemmal sheath which also shrinks considerably and is transformed into a protoplasmic cord.

Regenerative changes. In favourable circumstances regenerative processes begin as nearly as the fourth day following the injury, although, effective reparative changes appear after 30 days and is completed in eighty days' time.

At first the Nissls granules and the Golgi apparatus reappear, the nucleus assumes its central position and the cell acquires its normal shape and size. Subsequently sprouting neurofibrils from the proximal stump extend irregularly towards the distal stump through the scar tissue and finally some of them establish connection with the empty neurilemmal sheath of the distal segment. Then they grow through the sheath until they reach their final destination where they establish connection with the previous sensory or motor nerve endings which still persist (The frame-work of the sensory or motor nerve endings persists for many months following injury to the axon). Soon after the sprouting neurofibrils have established connection with the empty neurilemmal sheath the myelin sheath reappear. Sometimes the new nerve may terminate in a new situation in a new ending.

Blood supply of nerves. Nerve trunks in the limbs are supplied by blood vessels derived from the local arteries. The median, sciatic and optic nerves are supplied by arteria mediana, arteria nervi-ischiadi and the central artery to the retina respectively. The former two arteries are representative of the axial artery of the respective limbs.

Sensory end-organs. The sensory end-organs are specialised formations in the sensory nerve terminals which are of specific design to receive particular type of stimulation such as touch, pressure, pinprick, warmth etc. According to the nature of sensation they carry, the sensory end-organs may be classified into (i) end-organs of general sensibility and (*ii*) end-organs of special senses. The end-organs of general sensibility may be further sub-divided into *exteroceptors*, *proprioceptors* and *visceroceptors*. The proprioceptors and visceroceptors are sometimes collectively called *interoceptors*. Pain fibres are associated with all types of receptors of general sensibility. Thus when a particular area of the skin is gently pressed no pain is perceived except the sensation of pressure, but if the pressure is gradually increased there comes a stage when pain is experienced (pressure pains). This is due to association of the pressure receptor with pain fibres. Similarly other types of sensory receptors are also associated with pain fibres.

Exteroceptors. The exteroceptors are mostly found in the skin and are stimulated by external influences. They consist of end-organs for pain, heat, cold, touch and pressure sensations. Receptors of different special senses also fall under exteroceptors but for convenience they have been grouped together under "receptors of special senses".

End-organs for pain. These end-organs are formed by naked axons which split up into numerous branches in the form of a bush. Some of the filaments from the bushes may even penetrate into the epithelial cells. They are also widely distributed in the muscles, tendons, vessels etc. and are concerned with pain sensation. There are two types of pain, "first pain" and "second pain". The "first pain" is sharp and stinging, and its conduction is very rapid. The "second pain" is dull aching pain which is slowly conducted.

End-organs for touch. There are three types of end-organs for touch sensation namely (1) Merkel's disc, (2) Meissner's corpuscle and (3) the spiral fibres around the hair follicle.

(1) *Merkel's disc.* This is a specialised form of end-organ in which a single fibre splits up into numerous branches which are woven around a single cell so as to form a cusp-like disc. They are usually present in the highly sensitive areas such as lips, fingers and genitalia and are concerned with light touch.

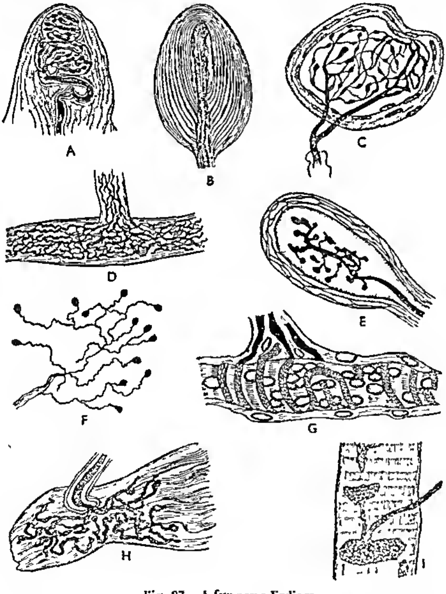


Fig. 97. A few nerve Endings.
A—Tactile or Meissner's corpuscle ; B—Pacinian corpuscles ;
C—End-bulb of Krause ; D—Organ of Ruffini ;
E—Organ of Golgi-Mazzoni ; F—Free nerve terminals ;
G—Muscle spindle ; H—Golgi bodies (Organ of Golgi);
I—End plates.

(2) *Astrocyte.* This type of neuroglial cell is found scattered throughout the central nervous system, both in the grey and white matters. They are of two types, *protoplasmic astrocyte* and *fibrous astrocyte.*

(a) The *protoplasmic astrocyte* is a peculiar cell with numerous branching protoplasmic processes. The cytoplasm is granular and shows the presence of numerous irregular processes. The protoplasmic astrocyte is usually found in association with grey matter.

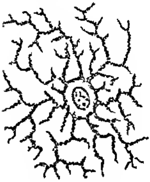


Fig. 99 Protoplasmic Astrocyte

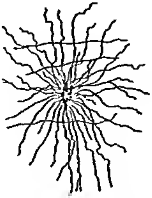


Fig. 100. Fibrous Astrocyte.

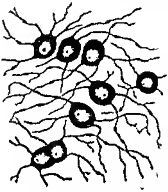


Fig. 101. Oligodendroglia.

(b) *Fibrous astrocyte.* They are found mostly in the white matter of the central nervous system and their cytoplasm shows the presence of numerous fibrillæ.

These cells are seemed to have definite relation with the blood vessels and are found to spread their processes in the form of a "T" around the fibrous sheath of the blood vessels. The nucleus is large and stains lightly with cresyl violet.

(3) *Ependyma.* These cells resemble epithelial cells and form a group by themselves which fall under the group mesenchymal epithelium. They line the ventricles of the brain and the central canal of the spinal cord.

(4) *Oligodendroglia.* These cells are present both in the grey and white matters but more so in the latter. Within the grey matter they are closely associated with the neuron. Their nuclei are spherical and are darkly staining.

EMBRYOLOGY

GENERAL INTRODUCTION

Embryology. Embryology is the science which deals with the formation and development of the embryo from the stage of fertilisation of the ovum to the birth of the fully formed fœtus. The embryological studies are confined to the life in "utero" which in man, covers a period of 10 lunar months or nine calendar months, and the series of changes that mould the fertilised ovum into a fully formed fœtus are compiled together under the subject of embryology.

Embryology can be studied from various angles to cover the details of the various embryological facts. When the study includes description of the embryological facts by direct observation we call it a *descriptive embryology*. The present day embryological studies are no more confined to descriptive embryology only but they include various experiments and chemical and biochemical analysis of different cells and tissues of the developing embryo.

The study of embryology by various experiments in the developing embryo is known as *experimental* or *casual embryology*. In experimental embryology some part of the developing embryo is either removed, destroyed or transplanted to a new site, and the changes suffered by the embryo by such experiments are noted. By such experiments various mechanical, functional and organising influences of many a structures in the growth of the whole embryo or its parts are revealed. As for example, during the late blastula or early grastula stage if the chorda-mesodermal cells (cells which form notochord and the somites) are destroyed it is seen that the overlying neural epithelium fails to develop. Thus it becomes evident that the local chorda-mesodermal cells exert some organising influences (cellular organiser) in the development of the neural epithelium.

Moreover, it is seen that when the chorda-mesodermal cells (Tail or Trunk organiser) are transplanted to another host embryo of the same age at the presumptive head level they induce formation of the head and trunk structures at the head level of the host embryo, and when transplanted to the trunk level they induce formation of the trunk and tail tissues only.

With the improved knowledge in biochemistry the field of study in embryology has greatly widened and attempts are being made to determine the *specific chemical factors* which are of great concern in various phases of growth processes. The study of embryology, which deals with the biochemical or chemical analysis of the cells and tissues of the developing embryo, is known as *biochemical* or *chemical embryology*. The chemical embryology may further be subdivided into *cytochemistry* and *histochemistry* depending on the nature of investigations done on either the cells or tissues.

Importance of embryology. Apart from its scientific interest the knowledge of embryology is essential for the understanding of the developmental anomalies which are so often seen in our professional life. Moreover, some of the anatomical facts in gross anatomy are difficult to be explained without their reference to embryology. New growths (tumours) are occasionally found to be formed from embryological remnants of some structures which normally retrogress during the process of development; unless one keeps in mind about the embryological facts of such structures it is difficult to understand about the origin of such new-growths. In some operative procedures the knowledge of embryology is utilised for a better approach which minimises the hazards of operation. Moreover, the study of structures in gross anatomy seems to be incomplete without any knowledge of their developmental background.

Some terms in embryology. It is of great interest to know as to how from a series of changes the single-celled fertilised ovum is converted into a multi-cellular complex organism, the fœtus, and that how the latter develops into an adult form. The series of changes that mould the fertilised ovum into the adult form are known as *ontogeny*.

The study of anatomy and embryology of different animals and other species reveals and explains many facts in human anatomy. A comparative study of human anatomy with that of animals is very much useful, particularly in embryology, and such a study is known as *comparative anatomy*.

Whenever each of the segments of a multisegmented form is seen to contain identical structures with similar arrangements, the segments are said to be *serially homologous*. Structures developing from similar cell-groups in the embryo in different animals are said to be *homologous* (similar in origin), although such structures in their adult form may be quite dissimilar, both in form and in function. The wings of a bird, the forelimbs of a quadruped and the upper limbs of man are homologous structures having the same ontogenic history. The term '*analogous*' is reverse to 'homologous' and denotes "similar in function but dissimilar in form and origin". Thus the lungs of man and gills of fishes are analogous structures, although they differ in their mode of origin and in their form. Another term often used in anatomy is "*morphology*" which may be defined as the science of the development of the forms of living organisms.

Evolution. The term "evolution" (e=out; volvere=to roll) means rolling out or changing. It is believed that the Earth we live in came into existence about 2000 million years ago. At first it was a red-hot mass which, it is believed, was a torn-out fragment of a similar larger heavenly body. The red-hot mass then gradually cooled down and acquired physical modifications in which a gaseous atmosphere came into existence and there were some collections of water. Ultimately after a period of about 1000 million years it cooled down considerably to become suitable for the existence of life. At first, plants and vegetations began to appear on the Earth's surface which were the sources of food for the animal life which appeared later. Thus the earlier Earth—a red-hot mass—which was unsuitable for the existence of any life, vegetable or animal, changed physically to become suitable for the existence of life. Astronomers believe that the solar system has also been changing since the first existence of the Earth. Thus with the change in physical environment of the Earth the plants and animals that exist on it are also changing gradually to adapt themselves to the new environment. *This gradual adaptation to the changing environment with accompanying changes in form and function is called organic evolution.*

Evolution of Man. Evolution of Man is a scientific curiosity which has led to numerous valuable researches but the matter still remains to be finally settled. The earliest living organism that came into existence during the earlier part of Earth's existence had to mould itself in the face of the realities of its unfavourable environment for the sake of survival. With continued progeny and for the survival of the species, the generation next in order inherited physical modifications to suit the new environment, and thus, as the ages rolled by, the species progressed and acquired physical modifications which differ from its ancestor—the evolution of Man can be traced back to its ancestor fish. The diagram on the next page depicts the "phylogenetic tree' representing the animal kingdom including man.

The evolutionary history about the origin of a species is known as *phylogeny*.

THE GERM-CELLS OR THE GAMETES

The mature sex cells in either sex are known as the gametes or the mature germ cells which are responsible for the continuance of the future progeny. The female gamete is the mature ovum and the male gamete is the mature spermatozoön. Each of these is a cell which is incapable of further multiplication by itself, but after mating, when the male gamete gets the opportunity of fusing with the female gamete a new cell is formed by their fusion which acquires a tremendous power of multiplication. For this the nucleus of the gametes of either sex is qualified with the term "pronucleus".

The *male pronucleus* derived from the head and the middle piece of the mature spermatozoön or the male germ-cell fuses with the *female pronucleus* of the mature ovum and this process is termed "*fertilisation of the ovum.*" The product of fertilisa

tion is a single cell that contains the "*segmentation nucleus*" formed by the fusion of the two pronuclei and this single cell is known as the *zygote*. By a process of cell division, cell migration, growth and differentiation this single-celled zygote later on leads to the formation of a *complex multicellular organism*—the fœtus—which has to undergo further development to attain full maturity.

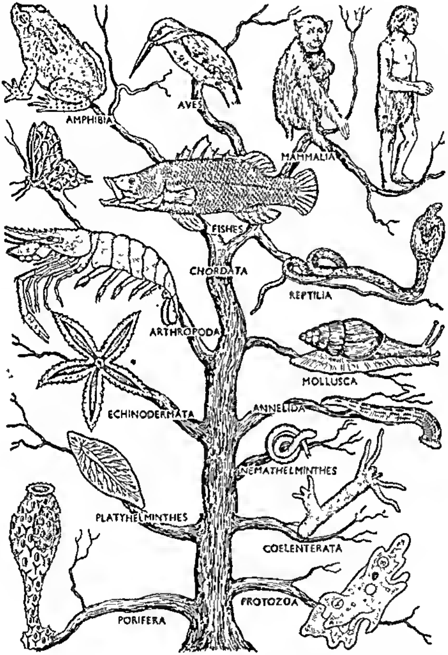


Fig. 102. "Phylogenetic tree" representing the animal kingdom. The lowest phylum is placed at the bottom and the highest at the top.

Before going into the details of the processes by which the single-celled zygote is *transformed into a fully formed fœtus, it would* be worth *mentioning about the* history of the germ-cells, the formation of the ovum or "oögenesis" and the formation of the spermatozoön or "spermatogenesis".

History of the Germ-cells. The single-celled zygote after fertilisation of the ovum, by the process of cell division, gives rise to innumerable cells which fall under

two main groups, the *somatic cells* and the *germ-cells*. The somatic cells are by far the most numerous from which almost all the tissues of the future human body are developed, whereas the germ-cells which form the negligible minority, are integrated in the formation of the sex glands, that is, the testes in the male and the ovaries in the female, and are responsible for sex determination and future progeny.

The germ-cells, in either sex, which are at first immature ones, undergo a series of changes towards their maturation and when matured, they are called *gametes*. The male gamete is known as the *spermatozoön* while the female gamete is known as the *mature ovum*. Usually three stages namely, *stage of multiplication*, *stage of growth* and the *stage of maturity*, are encountered in the life cycle of the germ-cells. During the *stage of multiplication* the primordial germ-cells multiply by mitotic cell division and form innumerable cells which are lodged in the sex glands, and are known as *spermatogonia* in the male and the *oögonia* in the female. During the *stage of growth* further multiplication by mitotic cell division ceases and the spermatogonia in the male and oogonia in the female grow up to form the *spermatocytes* and the *oocytes* respectively. During the *stage of maturation* the spermatocytes and oöcytes again divide but this division which is known as the *maturation division*, occurs twice only, that is, each cell divides twice resulting in 4 cells (two in the first division and two in the second division). Thus each spermatocyte results in the formation of 4 cells which are known as *spermatids*. The spermatids later on, by a process of metamorphosis, change into *spermatozoa*. Thus the male germ-cell passes through the following stages towards its maturity such as *spermatogonia*, *primary spermatocyte*, *secondary spermatocyte*, *spermatid* and *spermatozoon*. The similar stages in the female germ-cell are the *oögonia*, *primary oocyte*, *secondary oöcyte* and the *ovum*.

Of the two maturation divisions, the first is *heterotypical* or *reduction division* (meiotic division) in which the chromosomes do not split but half the number of total chromosomes passes to one of the resulting daughter cells and the remaining half to the other; thus the resulting daughter cell is having only half the number of chromosomes of its mother cell and such a division is called *heterotypical* or *reduction division or meiotic division*. The second maturation division is *homotypical*, that is, here each chromosome splits into two and each of the daughter cells is endowed with the same number of chromosomes with its mother cell.

THE MATURE OVUM

The mature ovum is roughly a spherical cell and measures about 100 to 200 microns in diameter. Like an ordinary cell the ovum consists of a cell body, a cell membrane, protoplasm, nucleus and nucleolus but when critically compared with an ordinary cell it differs from the latter in great detail (see table on page 90).

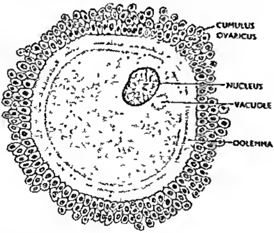


Fig. 103. A mature ovum.

It has become customary to call the nucleus of the ovum as the *germinal vesicle* and the nucleolus, the *germinal spot*, probably due to the important role they play in the process of reproduction. Similarly, the protoplasm of the ovum goes by the name the *yolk* or the *vitellus* because it provides nutrition during early embryonic development. It is also alternatively called *oöplasm*. The yolk or the cytoplasm of the ovum consists of substances similar to ordinary cell cytoplasm and can be split into two parts, *formative yolk*, and a large amount of fatty material in droplets called *deutoplasm*. It is this store of

fatty material in the ovum which is utilised during earlier part of embryonic development when other sources of nutrition are not available. The cell membrane of the ovum is called the *vitelline membrane* or *oölemma*. Because the vitelline membrane looks as a colourless zone around the yolk it is also alternatively called *zona pellucida*. It also goes by the name *zona striata* because under high power microscope it gives a striated appearance. The space between the vitellus (main body of oöcyte) and the vitelline membrane is called the *perivitelline space*. The polar bodies after being extruded out from the oöcyte are temporarily lodged into this space. When the ovum is discharged from the Graafian follicle, some of the follicular cells still continue to stick to the wall of zona pellucida and are found to form radially arranged columns of cells around it, and these radially arranged cells around the ovum are called *corona radiata*.

OÖGENESIS

The general conception about ova is that, they have a short life in the ovary, and that the ova that develop during fœtal life, all degenerate after birth and the definitive ova are formed from the "germinal epithelium" of the ovary. The cells from this epithelium proliferate to form "oogonia" which replace the degenerated ova. Although the above phenomenon is the usual sequence of events in some animals, it is still doubtful whether the same process is repeated in man. In human subjects it has been found that the superficial surface of the ovary in the young female children presents numerous small follicles and it is still a matter of controversy whether any new ova are formed after birth.

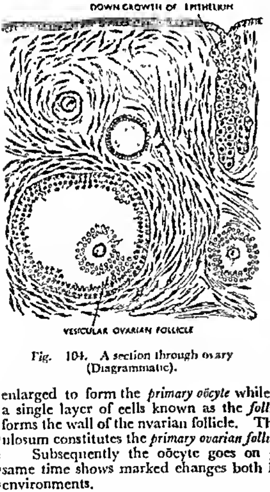


Fig. 104. A section through ovary (Diagrammatic).

In some animals the germinal epithelium on the surface of the ovary proliferates to form downgrowths of cells called the *Pfluger's tubes* or *"egg tubes"* which consist of single or several layers of cells. These tubes penetrate through the superficial fibrous tissue (stroma) of the ovary and subsequently are detached from the germinal epithelium to form different cell groups in the cortex which, later on, develop into ovarian follicles. In human beings, groups of cells arise *in situ* within the cortex which, at a later stage, are joined by the epithelial down-growths ("egg tubes") from the germinal epithelium on the surface of the ovary. One of the cells in each cell-group becomes enlarged to form the *primary oöcyte* while the remaining cells are flattened to form a single layer of cells known as the *follicular layer* or the *stratum granulosum* which forms the wall of the ovarian follicle. The oocyte together with the stratum granulosum constitutes the *primary ovarian follicle*.

Subsequently the oöcyte goes on growing. It enlarges in size and at the same time shows marked changes both in its internal structure and in its external environments.

Changes in the external structures. Externally the cells of the stratum granulosum, which form initially a single layer of flattened cells, become cubical in shape and multiply rapidly by mitotic cell division to form several layers of cells. Later on, these cells secrete a fluid called "liquor folliculi" which makes its room by splitting the cells of the stratum granulosum into two layers, inner and outer. The outer layer of cells is still called the stratum granulosum while the inner layer of cells, being

pushed to one side, is spread over the oocyte so as to form a heaped-up mass of cells within which the oöcyte lies. This heaped-up mass of cells containing the oöcyte is called the "*cumulus ovaricus*". Thus the primary ovarian follicle, which was a solid mass of cells, becomes the ***vesicular ovarian follicle,*** as it contains a cavity filled with liquor folliculi and into which the oocyte together with the "cumulus ovaricus" protrudes.

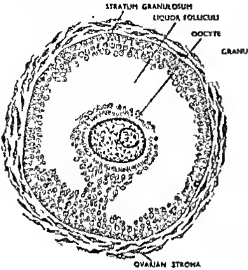


Fig. 105 A vesicular ovarian follicle

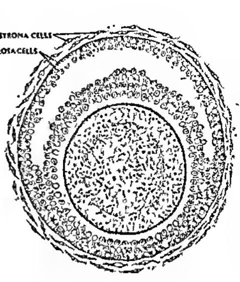


Fig. 106. An oöcyte just before first maturation division.
Note that the nuclei and the nuclear membrane have disappeared.

Internal changes. Concurrently with the above changes in the external form of the oocyte, changes also occur in its internal structure. The cytoplasm surrounding the oöcyte condenses to form a membranous envelope around the oöcyte known as the *oölemma* which later on forms the *zona pellucida*. Both the cytoplasm and the nucleus increase in volume and the cell body which was circular in general outline becomes oval in shape. The centrosome, which was visible earlier, disappears during or just before maturation. At maturation the oöcyte increases much in size and measures about 100μ to 200μ in diameter in its long axis.

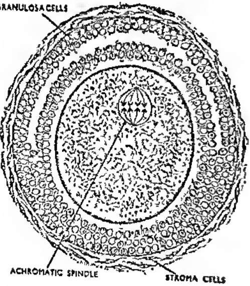


Fig. 107. An oöcyte in the process of first maturation division (heterotypical mitosis).
Note the formation of the achromatic spindle and the re-arrangement of the chromosomes in pairs.

With the completion of the stage of growth the oöcyte enters into the stage of maturity in which it divides twice—first by ***heterotypical mitosis*** and then by ***homotypical mitosis***—to form three cells of which two are smaller cells known as the ***polar bodies*** and one is a large cell called the ***mature ovum.***

During the first maturation division both the nuclei and the nuclear membrane disappear and an achromatic spindle is formed at one pole of the cell. The *chromosomes* re-arrange themselves in

pairs, of which half the number passes to one pole of the spindle and the remaining half to the other pole. Then the spindle rotates in its transverse axis so that, one of its poles carrying half the number of total chromosomes, forms a local projection from the cell wall and is known as the first *polar projection.* Later on a constriction

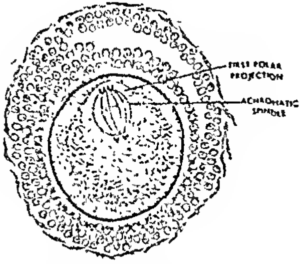


Fig. 108. An oöcyte in the stage of formation of first polar projection
Note that half the number of total chromosomes have passed to each pole of the spindle and the latter has rotated in its transverse axis to form the first polar projection.

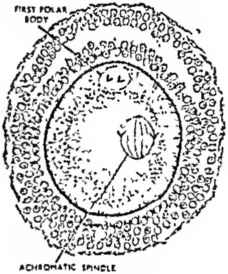


Fig. 109. An oocyte starts for homotypical mitosis.

appears around the projection which cuts off a portion of the cytoplasm together with half the number of chromosomes contained within the polar body. Thus the primary oöcyte or the oöcyte No. I is divided into a large cell, the *secondary oöcyte* or the oöcyte No. II and a small cell, the *first polar body* by the process of heterotypical mitosis or meiosis or reduction division.

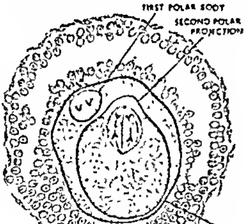


Fig. 110. A further stage of figure 109.
Note that equal number of chromosomes have moved to each pole of the spindle and the second polar projection has appeared.

The secondary oöcyte or the oöcyte No. II now becomes ready for second maturation division by the process of *homotypical* mitosis. The achromatic spindle is reformed within it and one of its pole forms the same type of projection of the cell wall known as the *second polar projection.* The chromosomes re-arrange themselves again in pairs and each is then split up longitudinally into two and thus the number of chromosomes becomes doubled up. Half the number of the chromosomes then move to one pole of the spindle and the remaining half to the opposite pole. Then in the same manner as in the formation of the first polar body the second polar body is separated. Thus the secondary oöcyte or the oöcyte No. II is divided into n small cell, the *second polar body* and a large cell, the *mature ovum.*

Subsequently in the matured ovum a nuclear membrane reappears around the chromatins (half of that contained in oöcyte No. I); then the nuclear retinaculum, and the nucleoli reappear and the chromatins rearrange themselves again to dispersed amongst the linin-retinaculum (nuclear retinaculum). Thus the

is completed. The mature ovum has all the complement of a typical cell except that it has no centrosome and that it contains only half the number of chromosomes of a somatic cell.

Difference between the ordinary somatic cell and the ovum

	Ovum	Somatic cell
Cell body	The cell body is much larger and measures about 100 to 200 microns in diameter. The outer cell envelope, the zona pellucida, is more resistant and presents radial striations when looked through high power microscope. Corona radiata forms a special outer covering of the discharged ovum	The cell body is comparatively much smaller. The cell membrane is more delicate and has no radial striations. No special outer covering is present.
Nucleus	It is large, vesicular and eccentric in position	It is smaller and central in position.
Centrosome	Mature ovum has no centrosome.	Centrosome is always present.
Power of reproduction	The ovum has no power of reproduction because it has no centrosome	Somatic cells are usually reproductive because of the presence of centrosome.
Chromosomes	Matured ovum (after reduction division) contains half the number of chromosomes of a somatic cell. They are transmitted to the offsprings.	Contains 24 pairs of chromosomes. They are not transmitted to the offsprings

Difference between the Oocyte and the Spermatocyte

	Oocyte	Spermatocyte
Structure	Covered externally by granulosa cells, the cell membrane becomes thickened to form oölemma, they are enclosed within follicles	No external covering; no envelope like oölemma; they have no follicular arrangement and are found as constituent cells of the wall of the seminiferous tubules.
Daughter cells	Daughter cells are of unequal size.	Daughter cells are of equal size.

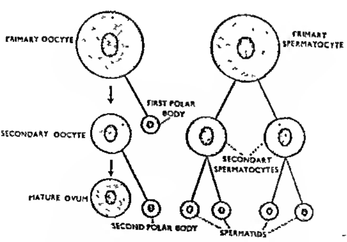


Fig. 111. Diagrammatic representations to show the difference between oögenesis and spermatogenesis.

THE MALE GERM-CELL OR SPERMATOZOÖN

The spermatid, which is a matured male germ-cell, is converted into a spermatozoön by the process of metamorphosis. The spermatozoön is a specialised cell which differs from ordinary cell in many respects. An ordinary cell consists of a cell body within which all the intracellular components are confined. As will be seen below the intracellular components of a spermatozoön are spread out in special formations which add to its characteristic features.

Compared to the ovum the spermatozoon is a much smaller cell, and its whole length, which is about 50μ, equals to that of the nucleus of the ovum. It consists of five parts namely *head, neck, middle piece* or *body, tail* and *end piece* which succeed one after another.

Head. The head forms the most expanded part of the cell and measures about 4.5μ in its long axis. It is oval in general outline and is compressed from side to side. It is completely invested by an outer envelope known as the "*head-cap*". The head-cap consists of two parts, anterior and posterior. The anterior part of the head-cap surrounds the nucleus and is known as the *head-cap proper* whereas the posterior part covers the portion of the head that lies behind the nucleus and is consequently called the *post-nuclear cap.* Internally the head contains the nucleus under cover of the head-cap proper.

Neck. The neck follows the head and forms the shortest segment which joins the head with the middle piece. It consists of a deeply staining chromaphil substance known as the *accessory body* or the *neck body.* Although it is still a matter of controversy, some believe that the "neck body" is a modified form of Golgi elements of an ordinary cell.

Middle piece or body. The middle-piece or the body of the spermatozoön forms the connecting link between the neck and the tail or the flagellum. It consists of proximal or the anterior centriole, distal or the posterior centriole, portion of the axial filament, the axial sheath and the mitochondrial sheath.

The *proximal* or the *anterior centriole* lies at the junction between the neck and the middle-piece while the *distal* or the *posterior centriole* lies between the middle-piece and the tail. It is ring-like and is pierced by the axial filament and its sheath. The *axial filament* is the central filamentous body which begins from the proximal centriole and passing down the body and tail ends in the end-piece. Except in the end-piece the axial filament is surrounded by a sheath formed out of condensation of a thin layer of protoplasm known as the *axial sheath.* In its course from the middle-piece to the tail the axial filament together with its sheath passes through the distal or the posterior centriole which is ring-like. Within the middle-piece, superficial to the axial sheath there is another sheath around the axial filament known as the *mitochondrial sheath* which is formed out of mitochondrial granules.

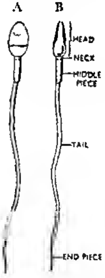


Fig. 112. Diagram of two spermatozoa.
A. Front view. B. Side view.

Tail or the Flagellum. It forms the longest segment of the spermatozoön and consists of axial filament with its axial sheath.

End-piece. The end-piece consists of the terminal portion of the axial filament which has lost its axial sheath.

SPERMATOGENESIS

The spermatozoa or the male germ-cells are modified cells which are developed within the testis and are discharged into the genital duct (vas deferens and urethra) through which it comes to the exterior along with the seminal fluid. Each consists of a head which contains its nucleus, a neck, a body or the connecting piece, a tail and an end-piece.

The earliest male germ-cells are known as the *spermatogonia* which are the normal constituent cells forming the deepest layer of cells on the walls of the seminiferous tubules of the testis. In the first phase of spermatogenesis, the spermatogonia multiply by cell division and the resulting cells are pushed out from the deeper zone of the walls of the seminiferous tubules towards its lumen and are known as the *primary spermatocytes*. The primary spermatocyte subsequently divides into two *secondary spermatocytes* by heterotypical mitosis in which the number of chromosomes are reduced to half. The secondary spermatocyte subsequently divides by homotypical mitosis to form two *spermatids* which contain deeply staining homogeneous nucleus which, later on, gives to the formation of the head of the future spermatozoa. The spermatids do not divide any further but they are transformed into the *spermatozoa* by a process of metamorphosis known as spermiogenesis. With the process of maturation of the male germ-cell from a spermatogonium to a spermatozoön, the cell continually moves towards the lumen of the seminiferous tubule till it lies free in the lumen.

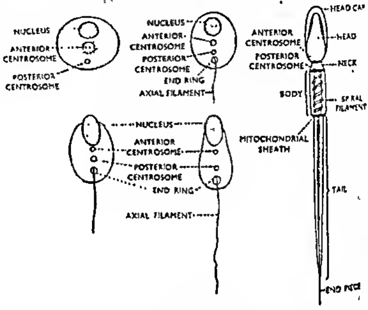


Fig 113. The metamorphosis or the transformation of the spermatid into spermatozoon.

Metamorphosis of the spermatid into the spermatozoön or spermiogenesis. The differentiation of the spermatid into a spermatozoön is an ingenious, striking process in which the nucleus suffers a great change and there is modification of the cytoplasm and its constituents. The nucleus, which is confined to the head, either contracts or is elongated in an attenuated form. A portion of the Golgi substances, together with some amount of cytoplasm is modified to form the head-cap proper. The post-nuclear cap is formed out of a thickened membrane in association with the anterior centriole. The centrioles are arranged in proximal-distal formation. The mitochondrial substances are condensed to form the axial sheath. The axial filament is formed in relation to the anterior and posterior centrioles and then grows backwards through the middle piece and the tail. The cytoplasm is modified and is drawn backwards from the head region to form a sheath for the head, neck, middle piece and part of the tail. Excess of cytoplasm, Golgi and mitochondrial substances are cast off during the process of metamorphosis.

SEX VARIABILITY AND CHROMOSOME REDUCTION

Each somatic cell contains 23 pairs of chromosomes which are autosomes, that is, all of them are of same type, whereas each germ-cell contains 22 pairs of autosomes and one pair of sex chromosomes. In the female the two sex chromosomes are similar to each other and are known as 'X'-chromosomes while in the male the two sex chromosomes differ from each other and one is a 'X'-chromosome derived from the mother, and the other is a "Y"-chromosome of paternal origin.

Like somatic cells the spermatogonia and the oögonia contain 23 pairs of chromosomes of which 22 pairs are autosomes and one pair of sex chromosomes. During reduction division of the germ-cells half the number of chromosomes passes to the resulting daughter cells so that each daughter cell contains 22 autosomes and one sex chromosome. In the female the sex chromosome in the daughter cell is the 'X'-chromosome but in the male it may be either "X" or "Y"-chromosome.

When fertilisation takes place, sperm containing 22 autosomes and "X"-or "Y"-chromosome fuses with the ovum which also contains 23 autosomes and one 'X'-chromosome, and consequently, the resulting cell contains the usual somatic number of chromosomes, that is, 23 pairs. If a sperm with 22 autosomes and one 'X'-chromosome unites with an ovum which also contains 22 autosomes and one 'X'-chromosome, the resulting cell contains 44 autosomes and 2 sex chromosomes of the same type (x+x) and the sex in this case will be a female. If on the other hand the male sperm with 22 autosomes and one "Y"-chromosome enters the ovum (containing 22 autosomes and one sex chromosome or the x-chromosome) the resulting cell will contain 44 autosomes and X and Y sex chromosomes and the resulting sex would be a male.

STAGES OF DEVELOPMENT

The study of embryology concerns pre-natal life only which usually covers 9 calendar months or 10 lunar months. The pre-natal life can be sub-divided into (*a*) pre-embryonic period (*b*) embryonic period and (*c*) fœtal period.

(a) Pre-embryonic period. The pre-embryonic period begins with the formation of the single-celled zygote, as a result of the fertilisation of the ovum, and extends for about two weeks. During this period the single-celled zygote multiplies rapidly by segmentation, differentiates into embryonic and non-embryonic portions and is embedded into the uterine endometrium which has been transformed into what is known as "decidua". The shape and form of the embryo have not yet developed.

(b) Embryonic period. It extends from the end of pre-embryonic period to the end of the second month and during this period, although definite form and shape of human being cannot be identified, rudiments of almost all the organs are formed and can be identified.

(c) Fœtal period. This period succeeds the embryonic period and extends from the end of the second month to the birth of the fœtus. This is the period when the growth manifestations are markedly prominent, particularly during the last few days prior to birth. The growing embryo assumes definite human form during this period and is transformed into the "fœtus".

PRE-EMBRYONIC PERIOD

Fertilisation

The union of the male gamete with the female gamete to form a zygote is known as the *fertilisation*. The discharged oocyte surrounded by corona radiata has undergone a stage in which the first polar body has been extruded and the second maturation spindle is being formed when it is penetrated by the spermatozoön and the union between the two usually takes place within the outer or ampullary part of the

uterine tube. It is believed that the entire sperm penetrates into the ovum and after some time the middle piece and the tail are no longer detected and presumably they are absorbed by the cytoplasm of the ovum. After the entry of the sperm, the second polar body of the ovum is extruded and the chromosomes re-arrange themselves with-

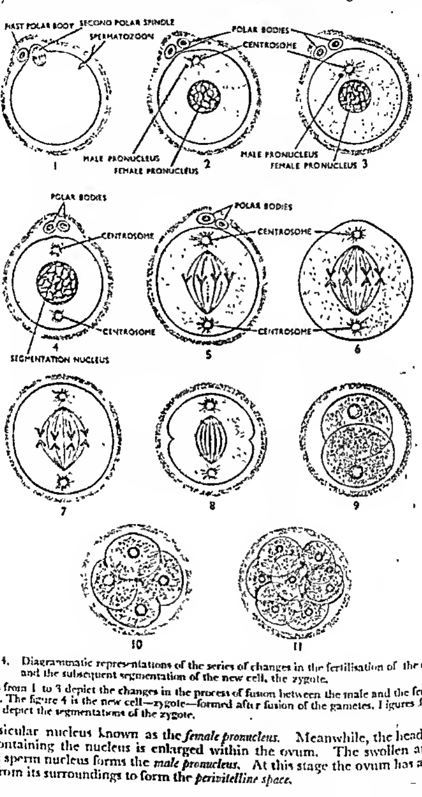


Fig. 114. Diagrammatic representations of the series of changes in the fertilisation of the ovum and the subsequent segmentation of the new cell, the zygote.

Figures from 1 to 3 depict the changes in the process of fusion between the male and the female gamete. The figure 4 is the new cell—zygote—formed after fusion of the gametes. Figures from 5 to 11 depict the segmentations of the zygote.

in its vesicular nucleus known as the *female pronucleus*. Meanwhile, the head of the sperm containing the nucleus is enlarged within the ovum. The swollen and the enlarged sperm nucleus forms the *male pronucleus*. At this stage the ovum has already shrunk from its surroundings to form the *perivitelline space*.

The male pronucleus then rotates through 180° angle and gradually approaches the female pronucleus towards the centre of the ovum and the union of the two pronuclei takes place exactly in the centre of the cell to form a single nucleus known as the *segmentation nucleus* which contains full number of chromosomes, that is, 48 in number. The single cell formed after the union of the two pronuclei is called the *zygote* which is possessed of full complements of a typical cell and contains all the potentialities of the parents.

SEGMENTATION AND FORMATION OF MORULA AND BLASTULA

After the union the centrosome derived from the proximal centriole of the sperm makes its appearance and passes to the periphery of the cell and then divides into two, each passing to each pole of the cell. The united pronuclei lose their nuclear membrane and their chromosomes re-arrange themselves, and each chromosome divides longitudinally into two, one passing to each pole of the cell to the centrosome. Then opposite the equator of the spindle there develops a furrow which gradually deepens and ultimately two cells are formed (two-celled stage) and thus the zygote passes to the stage of segmentation in which multiplication of cells occurs by repeated cell divisions. Segmentation continues by the process of mitotic cell division and results in the formation of a mass of cells known as the *morula*. It is so named because the newly formed cell-mass resembles a mulberry in appearance. The morula is then carried to the uterine cavity by the movement of the cilia of the ciliated epithelium of the uterine tube and by the rhythmical contractions of the musculature of the uterine tube. This journey from the uterine tube to the uterine cavity takes about six days since fertilisation of the ovum.

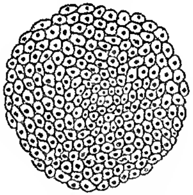


Fig. 115. The Morula.

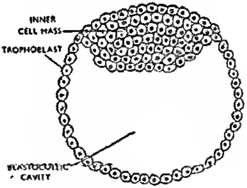


Fig. 116. The Blastula.

The time the morula reaches the uterine cavity the endometrium is in its luteal phase in which the latter has become considerably thick and vascular, and its glands are pouring out their secretions into the uterine cavity. As a result the whole uterine cavity is covered with a film of mucus into which the morula floats. Then the morula undergoes a physical modification in which the fluid from the uterine cavity enters within the cells of the morula, the outer cells of the morula acting a dialysing membrane. *This fluid derived from the endometrial mucus provides nutritive elements and oxygen to the morula at this stage.*

The fluid imbibed by the morula makes its room within it and thus, the morula, which was a solid cell mass, develops within, a cavity filled in with fluid, and the latter splits the cell mass into an *inner cell-mass* and an outer flattened layer of cells, the *trophoblast*. The morula, at this stage, which contains a single cavity within (blastocœle), is called the *blastocyst* or the *blastula*.

IMPLANTATION OF BLASTOCYST

The hypertrophied endometrium at this stage becomes rough and irregular with depressions and elevations. Most of the depressions are formed by the wide mouths of the endometrial glands and the blastocyst which is smaller than the opening of the endometrial glands is lodged into one of these openings preliminary to the final implantation in between the glands. The outer layer of cells of the blastocyst is now called the *trophoblastic cells*. Later on, the trophoblastic cells become fused with the endometrial epithelium between its columnar cells. The attaching cells of the trophoblast is called the *attaching trophoblast*. Later on, the area of contact of the endometrial epithelium undergoes degenerative changes, probably due to an enzyme secreted by the attaching trophoblast, and the blastocyst gradually sinks down into the endometrium and gains a wider area of contact. Then the invading trophoblastic cells reach the stroma of the endometrium which becomes swollen, œdematous and congested due to the same enzymatic action. The growing trophoblast at this stage derives its nutrition from the tissue fluid of the œdematous and congested stroma. Subsequently the trophoblastic cells at the area of contact become thickned and differentiated into two layers, inner and outer. The inner layer is called the *cytotrophoblast* or *Langhan's layer* and the outer layer is called the *syncytium* or the *plasmodiotrophoblast* which lies in direct contact with the maternal tissues. The syncytial layer rapidly grows and spreads out into the stroma which, due to degenerative changes, contains much of tissue fluids and extravasated blood. The tissue fluid together with the extravasated blood is called *embryotrophe* from which the embryo at this stage derives its nutrition through its syncytial layer.

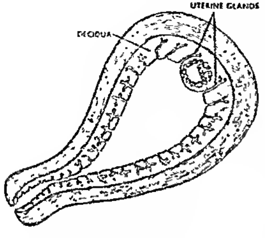


Fig. 117. Implantation of blastocyst in the uterus (Diagrammatic).

The point of entry into the uterine endometrium is gradually closed by a coagulum of fibrin and by the growth of the surrounding uterine epithelium. The above method of implantation is called *interstitial implantation* and the ovum from its discharge up to its implantation into the stroma covers a period of about eleven days and *the normal site of implantation is in the endometrium at the upper posterior wall of the body of the uterus.* After complete implantation the blastocyst lies in the superficial part of the stratum compactum and produces a slight elevation into the uterine cavity. The uterine endometrium after the implantation is called the *decidua*.

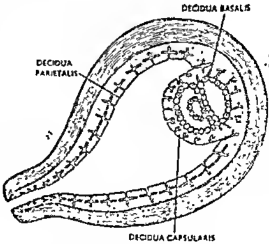


Fig. 118. The decidual changes of the uterine endometrium.

Decidua. The uterine endometrium after implantation of the blastocyst passes through a stage of "decidual re-[illegible]on" under the influence of progesterone (corpus luteum hormone) in which

both the stromal cells of the endometrium as well as the epithelial cells lining the uterine cavity are converted into large, oval, glycogen containing epitheloid cells known as the *decidual cells.* The uterine endometrium after decidual changes is known as the *decidua.*

The decidua that overlies the blastocyst is called the *decidua capsularis,* that intervenes between the blastocyst and the myometrium is called the *decidua basalis* and that lines the rest of the uterine cavity is called the *decidua parietalis.*

Characteristic changes. The uterine endometrium after decidual changes becomes considerably thick, and both the stromal cells and the lining epithelial cells are converted into decidual cells. It can be divisible into three zones, a superficial thin compact layer known as the *stratum compactum,* an intermediate less compact thicker layer known as the *stratum spongiosum* and a less thick unaltered deepest layer known as the *stratum basale.*

The uterine glands become tortuous and coiled in the region of the stratum spongiosum and stratum compactum while the portions extending into the stratum basale do not suffer any change. The uterine vessels become very much enlarged, coiled and tortuous. Their walls become thicker due to proliferation of the subendothelial cells and thickening of the elastic laminæ. These arterial changes affect the stratum spongiosum and stratum compactum only.

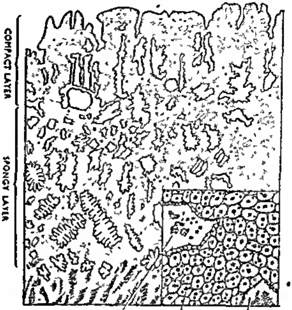


Fig. 119. A section through decidua to show its compact and spongy layers and the decidual cells (Diagrammatic).

The nature of the decidual reaction. The decidual reaction affects the endometrium of the body and the fundus of the uterus only. The endometrium of the cervix uteri does not show any decidual reaction. The reaction is associated with pregnancy and starts after implantation of the blastocyst. Milder degree of decidual reaction is also noticed in the uterine endometrium during the fourth week of menstrual period.

In the presence of adequate amount of progesterone in the circulating blood, decidual reaction of the uterine endometrium may also be produced artificially by irritating the uterine endometrium by foreign bodies such as needle, thread etc.

ABNORMAL SITES OF IMPLANTATION

Normally the fertilised ovum is implanted in the endometrium at the upper part of the posterior wall of the body of the uterus. In abnormal cases it may be implanted in the endometrium in close proximity to the internal os giving rise to a condition known as the *placenta prævia.* It may, however, be implanted elsewhere other than the uterine cavity and the condition of extrauterine implantation is known as the *ectopic gestation.* In ectopic gestation the implantation may take place either in the uterine tube or in the ovary itself or in the general peritoneal cavity. The intratubal implantation is known as the *tubal pregnancy* in which there is usually rupture of the tube during the second month of pregnancy causing severe internal hæmorrhage to the mother and the death of the embryo. In some cases after tubal rupture the embryo survives and is secondarily implanted into the neighbouring peritoneum giving rise to a condition known as the *secondary abdominal pregnancy.* It has been observed that *primary ovarian implantation* may take place in some cases but

in fact, this is secondary to the rupture of the tubal pregnancy. Although opinion varies, the usual cause of ectopic gestation may be the delay in the passage of the ovum through the uterine tube due to chronic inflammation of the same (chronic salpingitis).

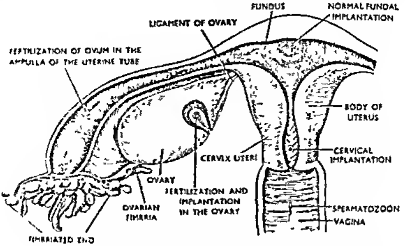


Fig. 120. The female reproductive organs showing the passage of the spermatozoon and the different sites of implantation.

FORMATION OF GERMINAL LAYERS AND THE EMBRYONIC AREA

The morula after its entry into the uterine cavity undergoes physical changes in which, fluid from the uterine cavity passes into it through its outer layer of cells and converts it into a blastocyst. The cavity of the blastocyst containing the fluid is called the *blastocele*. The fluid of the blastocyst makes its room within the morula by displacement of the cells within it. The cells are irregularly displaced, so that, there is a mass of cells on the inner aspect known as the *inner cell-mass* and a single layer of flattened cells on the outer aspect known as the *trophoblast*.

The trophoblastic layer is separated from the inner cell mass by the blastocele cavity in the greater part of its extent but remains connected with the same opposite the inner cell-mass.

Then a single layer of cells becomes isolated from the blastocelic surface of the inner cell-mass and is called the *entodermal cells*. The remaining cells of the inner cell-mass constitute the *embryonic ectoderm* which is also called the *formative cells*. The ectodermal cells then become aggregated to form a flattened disc. The flattened ectodermal disc or the *embryonic disc* separates itself from the flattened trophoblastic cells (amniogenic cells) opposite the centre but remains fused with the same at the periphery and thus a cavity forms between the amniogenic cells and the ectodermal disc and is called the *amniotic cavity*. The cells of the ectodermal disc are called the *embryonic ectoderm* which gives rise to the formation of the embryo while the amniogenic cells form the *amniotic ectoderm*.

The entodermal cells which have already been isolated from the inner cell mass spread over the outer peripheral margin of the ectodermal disc and then by proliferation and extension, lines the whole of the inner aspect of the blastocyst and thus another cavity, the *primary yolk sac*, larger than the amniotic cavity, develops concurrently with the latter. The cells of the primary yolk sac are of two types; those covering the ectodermal disc are of cuboidal type and are known as *embryonic entoderm* while those lining the trophoblast are flattened type of cells and are known as *yolk sac entoderm* or *extra-embryonic entoderm*. At this stage the unilaminar ectodermal disc becomes bilaminar together with the entodermal cells and this bilaminar plate forms the *embryonic area* or *germ disc* from which the embryo develops. Subsequently a single layer of cells, the *primary extra-embryonic mesoderm*, appears between the entoderm and the inner aspect of the trophoblast and are derived possibly from the latter.

The cells of the primary extra-embryonic mesoderm proliferate and form a network of cells between the primary yolk sac and the trophoblast and isolate the

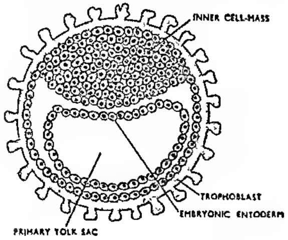


Fig. 121. Formation of entodermal vesicle from the inner cell-mass.

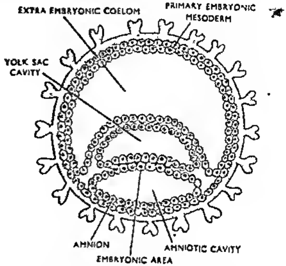


Fig. 122. Formation of ento- and ectodermal vesicles, extra-embryonic cœlom and the primary mesoderm.

former from the latter. The reticular, loose primary extra-embryonic mesoderm is called the *magma reticulare* which displaces the primary yolk sac and makes it smaller.

Formation of extra-embryonic cœlom. The extra-embryonic cœlom at first appears as two clefts, one on each side, in the mass of loosely packed cells of primary mesoderm that intervenes between the trophoblast, and the primary yolk sac and the embryonic area. These two clefts gradually enlarge and finally they run together to form a single cavity known as the *extra-embryonic cœlom.* The extra-embryonic cœlom thus splits the primary mesoderm into two layers, one lining the inner surface of the trophoblast and the other lining the embryonic area, which are separated from each other everywhere except at the ends of the embryonic area where

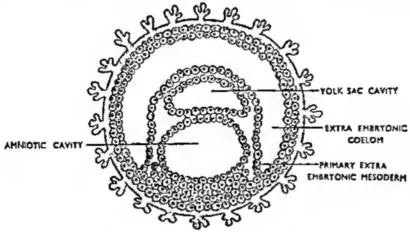


Fig. 123. A further stage of figure 122.

the two layers are continuous with each other. The primary extra-embryonic meso- 'erm that lines the inner aspect of the trophoblast is called the *extra-embryonic leuric mesoderm* and together with the trophoblast it forms the *chorion.* T' mbryonic primary mesoderm that lines the outer aspect of the primary alled the *extra-embryonic splanchnopleuric mesoderm.*

Later on, the extra-embryonic cœlom, by extension, isolates the ... ogether with the amniotic cavity from the trophoblast except at one end w'

embryonic area remains connected with the trophoblast to form the rudiment of the future umbilical cord. Thus it appears that the embryonic area together with its stalk of connection with the trophoblast is invaginated into the extra-embryonic cœlom lined by primary mesoderm.

EMBRYONIC AND FŒTAL PERIOD

In this period, with the formation of the embryonic area, growth and differentiation become the most prominent feature in the latter area which results in the formation of the embryo in which features of human form are not recognisable but rudiments of all the viscera can be identified. The embryo gradually assumes features resembling human form and gives rise to the formation of the fœtus.

The growth changes at this stage occur so much in quick succession that clear cut demarcation between the embryonic and fœtal periods cannot be identified and as such, the changes that occur during these periods have been dealt together.

The most conspicuous changes that follow in quick succession in the embryonic area are the formation of primitive streak, primitive node, intra-embryonic mesoderm, neural groove and the notochord which have been discussed in the following few pages.

FORMATION OF PRIMITIVE STREAK, INTRA-EMBRYONIC MESODERM AND NEURAL GROOVE

At the caudal end of the embryonic disc the ectodermal cells show differentiation in growth and the cells here rapidly proliferate and as a result, the proliferated cells produce a linear thickening which bulges towards the amniotic cavity. This is known as the *primitive streak.* Due to compactness the ectodermal cells of the primitive streak become rounded, lose their basement membrane and divide rapidly. Due to compactness of space some of the newly formed cells spread out laterally and caudally between the entoderm and ectoderm and form a distinct group which gives rise to the formation of the *secondary mesoderm* or *intra-embryonic mesoderm.* Caudally the cells of the secondary mesoderm migrate behind the posterior edge of the amnion to form the *secondary mesoderm of the connective stalk.* Thus with the formation of the intra-embryonic or secondary mesoderm the earlier bilaminar embryonic disc becomes a trilaminar one consisting of ectoderm, entoderm and intra-embryonic mesoderm except opposite the prochordal plate and the cloacal membrane (*see* later).

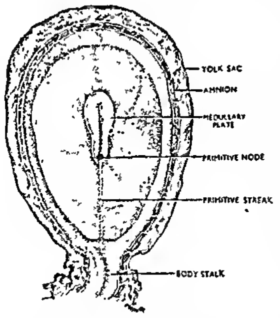


Fig. 124. The embryonic area.

Later on, at the anterior end of the primitive streak growth becomes more pronounced and is marked by an elevation known as the *primitive node or knot* or *Hensen's node.*

Soon after the formation of the primitive node the ectodermal cells anterior to its cephalic end differentiate and become thickened to form the *medullary plate* which gradually extends caudally beyond the primitive node. The cells of the neural or medullary plate undergo rapid proliferation and there is longitudinal infolding of the medullary plate to form a shallow groove known as the *neural groove*

[he neural groove gradually deepens and its lateral margins become raised to form he *neural folds*. The neural folds gradually approach each other and finally they use together in the mid-line to form a ubular structure, the *neural tube* or *eural canal*. The fused dorsal surface of the neural tube remains connected vith the surface ectoderm by a linear vall of cells for sometime and then becomes separated from it; then a group of cells appears in the angle between the ieural tube and the surface ectoderm alled the *neural crest*. The nervous sysem develops from the neural tube and he neural crest (see later).

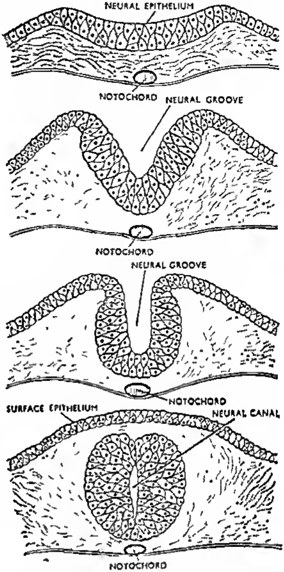


Fig. 125. The changes in the process of development of the neural tube.

THE NOTOCHORDAL PROCESS & THE NOTOCHORD

After the formation of the primiive node the ectodermal cells at the entre of the node undergo invagination owards the entodermal vesicle to form a small recess known as the *blastopore*. Then a cord of cells from the primitive iode projects forward along the middle ine and intervenes between the floor of he ectodermal neural tube dorsally and he entodermal vesicle ventrally. This ord of cells is called the *notochordal* or *ead process*. Thus it is found that *the rimitive streak gives origin to two important tructures, namely, the notochord from its ephalic end and the intra-embryonic or econdary mesoderm from its sides.*.

The anterior end of the notochordal process becomes fused with the *prochordal plate*, a thickened layer of endodermal cells at the anterior end of he embryonic disc. The entoderm of he prochordal plate remains fused with he ectoderm without any secondary mesoderm intervening between them and because, in future, this fused bilaminar membrane intervenes between the primitive pharynx and the primitive buccal cavity it is called the *buccopharyngeal membrane*. Thus the notochordal process is more or less fixed by its fusion with the prochordal plate. The ectodermal invagination at the summit of the Hensen's node (Blastopore) then elongates and invades into the notochordal process so as to canalise it and to form the *neurenteric* or the *notochordal canal*. With further growth, the notochordal process lengthens in size and the anterior end of the notochordal process being fixed with the prochordal plate he lengthening of the embryo takes place in a caudal direction. Further extension of the blastopore leads to openings in the floor of the neurenteric canal and the two cavities, the amniotic cavity and the yolk sac, are communicated to each other. All he openings in the floor of the neurenteric canal become confluent and a groove appears on the undersurface of the notochordal process. This groove then gradually widens and forms a shallow plate of columnar cells known as the *notochordal plate*. Thus the notochordal process which formerly intervened between the entoderm and the ectoderm becomes intercalated with the entoderm in the median plane, and

the embryonic entoderm at the roof of the yolk sac is divided into right and left halves by the intervening notochordal plate. Then the entodermal cells of the notochordal plate bridge over the notochordal process opposite the median plane and bury the same which has now been completely separated and has formed the *definitive notochord.*

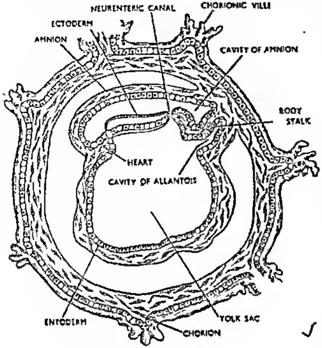


Fig 126 Formation of neurenteric canal.

Functions of notochord. In the vertebrates the notochord in its primitive form fulfils the purpose of central axis of support, and as the vertebral column is formed around it, the notochord is believed to be the predecessor of the vertebral column. It is believed that the notochordal cells produce two hormones, one is responsible for the conversion of the overlying ectoderm into nerve cells and the other is responsible for the differentiation of the para-axial mesoderm into sclerotome, myotome and dermatome.

Thus the notochord is an essential structure during the early embryonic stage and is responsible for the development of the spinal column, central nervous system and for the differentiation of the para-axial mesoderm into tissues mentioned above.

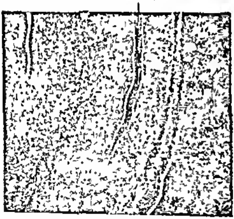


Fig. 127. Developing vertebral bodies with the notochord in the centre. (Microphotograph)

Fig. 128. Developing vertebral bodies with basiocciptal (Microphotograph). Note the up-turned end of the notochord extending into basiocciptal. Fibrous remains of this portion of the notochord forms the apical ligament.

In amphioxus the notochord exists as a permanent structure and forms the main spinal axis.

Fate of notochord. In man the notochord after its origin from the primitive . at first, forms a rod of cells, then it forms a tube and ultimately it is conver-

ted into a solid rod composed of cells of a peculiar type. Subsequently it is surrounded by a sheath, the *notochordal sheath* derived from the cells at the inner part of the somites. The notochordal sheath provides for the skeletal basis of the future vertebral column and the basioccipital and part of the basisphenoid bones of the skull.

During the second month of fœtal life due to constricting effect of the developing sclerous tissue in the notochordal sheath the notochord begins to disappear. Ultimately at a later stage the notochord completely disappears except in the intervertebral discs where its remnants exist as the nucleus pulposus. The apical ligament which connects the apex of the odontoid process of the second cervical vertebra with the basilar part of the occipital bone is also believed to be its fibrous remnant.

In amphioxus which forms the connecting link between the vertebrates and the invertebrates, the notochord exists as a permanent structure and forms the main spinal axis.

FORMATION OF HEAD, TAIL AND LATERAL FOLDS

Head-fold. An epidermal outgrowth, during the late gastrula stage, extends above the general tissues of the blastoderm at the wider extremity of the developing embryo so as to form a rudimentary fold which projects ventralwards, known as the *headfold*. This rudimentary epidermal fold contains within it the entodermal fold, the invaginating neural plate material (the developing neural tube) and the notochord which intervenes between the entoderm and the developing neural tube. Soon after, the primitive head fold forms a cylindrical head-outgrowth which is an epidermal tubulation containing within it the entodermal and the neural tubulation and the notochord which intervenes between the entodermal and the neural tubes.

Tail-fold. The tail-fold is also formed similarly as the head-fold at the opposite extremity of the developing embryo and is bent ventralwards. This is also an outgrowth of the tubulation process in which the outer tubulation is formed by the epidermal cells within which there lie the tail portion of the neural and entodermal tubes and the tail-end of the notochord which intervenes between the neural and the entodermal tubes.

Lateral-folds. Opposite the intervening area between the head and the tail-folds (future trunk region) there is ventral constriction of the ventro-lateral areas of the developing embryo so as to form two lateral folds, one on each side, which gradually converge towards the median plane. The epidermal, mesodermal and entodermal folds come together in the formation of each lateral fold. Initially the embryonic margin corresponds with the margin of the embryonic area but later on, with the formation of the right and left lateral folds, the embryonic margins form the boundary of a large orifice, the *primitive umbilical orifice*. The primitive umbilical orifice communicates the extra-embryonic cœlom with the intra-embryonic cœlom and transmits the intestinal loop.

THE FATE OF THE INTRA-EMBRYONIC MESODERM

As already stated the intra-embryonic mesoderm is derived from the ectodermal cells of the primitive streak. The intra-embryonic mesodermal cells spread laterally between the ectoderm and the entoderm and meet the extra-embryonic mesoderm at the lateral edge of the embryonic disc. They also extend laterally on either side of the notochordal process. Thus the embryonic disc which was bilaminar (ectoderm and entoderm) becomes trilaminar (ectoderm, entoderm and mesoderm). Within the embryonic disc it is present everywhere except (1) the prochordal region, (2) the region of the cloacal membrane and (3) the region opposite the median plane from the Hensen's node to the anterior end of the notochordal process.

Concurrently with the formation of the neural groove the intra-embryonic mesoderm on either side of the definitive notochord forms a longitudinal thickened band known as the *paraxial mesoderm*. The paraxial mesoderm on each side becomes

gradually thinned out to form the *lateral plate mesoderm* which in turn is continuous with the extra-embryonic mesoderm at the lateral margin of the embryonic disc. The constricted portion between the two constitutes the intermediate cell-mass.

Paraxial Mesoderm. As has already been noted the paraxial mesoderm forms a longitudinal mass of embryonic mesodermal condensation on either side of the notochord and the neural tube. Before it attains full length each bar of paraxial mesoderm shows signs of transverse segmentations which appear in series from above downwards. The first transverse cleft appears opposite the region of the hind brain and then successive clefts appear in series from above downwards and ultimately the longitudinal mesodermal bar is divided into about 41 or 42 triangular blocks known as the *somites*. The portion of the embryonic mesodermal bar that extends above the middle of the region of the hind brain does not show any sign of segmentation and forms the *cephalic mesoderm*.

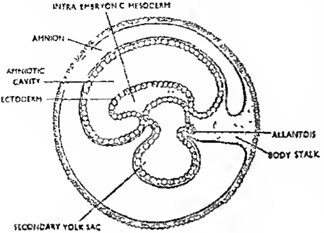


Fig. 129. A schematic section of the embryo to show the position of secondary mesoderm.

Each somite which at first forms a solid mass of cells soon exhibits a cavity within it known as the *myocele*. Each somite later on can be divided into ventro-medial and dorso-lateral portions. The ventro-medial part is known as the *sclerotome* while the dorso-lateral part is known as the *myotome*.

Sclerotome. The cells of the sclerotome rapidly multiply and migrate towards the sides of the notochord and the neural tube and form a special variety of cells known as the *mesenchyme*. Subsequently these scleratogenous cells spread medially to become continuous with the similar cells of the opposite somite and also extend caudally and cranially to become continuous with the cells of the adjacent somites. Thus the neural tube and the notochord are completely surrounded by a membranous sheath known as the *membranous vertebral column* derived from the scleratogenous cells of the sclerotome. The cells of the membranous vertebral column later on differentiate to form the vertebral column with its ligaments and the duramater of the brain and spinal cord. In other words the sclerotome of the paraxial mesoderm gives rise to the formation of the vertebral column and its ligaments as well as the duramater of the brain and spinal cord.

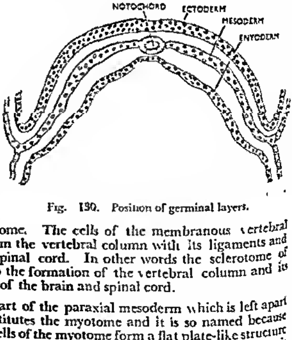


Fig. 130. Position of germinal layers.

Myotome. The dorso-lateral part of the paraxial mesoderm which is left apart after migration of sclerotome, constitutes the myotome and it is so named because ... are derived from it. The cells of the myotome form a flat plate-like structure whose dorsal and ventral ends are curved inwards and this plate-like structure is

known as the *muscle-plate.* Subsequently the outer part of the muscle-plate further differentiates to form the mesodermal integuments and is known as the *dermatome* or *cutis-plate* while the rest of the muscle-plate develops into muscle fibres.

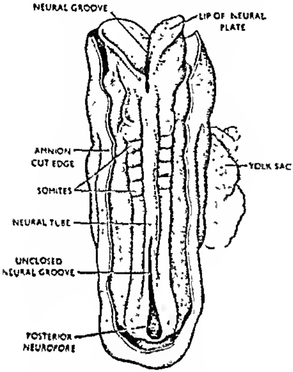


Fig. 131. Embryo with four somites formed by segmentation of the paraxial mesoderm.

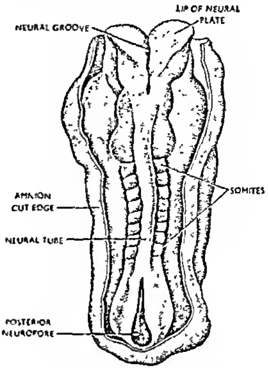


Fig. 132. Embryo with eight somites.

Cephalic mesoderm. The cephalic mesoderm can be divisible into two parts —segmented and unsegmented parts.

The *segmented part* of the cephalic mesoderm lies opposite the caudal part of the hind brain and consists of four segments on each side known as the *occipital somites.* The sclerotome of the occipital somites gives rise to the formation of the occipital bone and the duramater of the brain in the region while their myotomes form the intrinsic muscles of the tongue.

The *unsegmented part* of the cephalic mesoderm lies cephalic to the lower part of the hind brain and from it the rest of the muscles, bone, duramater and other connective tissues of the head region are formed.

The Intermediate cell-mass. The intermediate cell-mass intervenes between the paraxial mesoderm and the lateral plate mesoderm and forms a continuous column of cells. Its cells give rise to the formation of the excretory structures which are arranged in relation to the somites and are often called *nephrotomes.* The kidney, renal pelvis, ureter, a small portion of the urinary bladder, vas deferens in the male and the round ligament of the uterus in the female are developed from it.

The lateral plate mesoderm. Isolated cavities appear within the lateral plate mesoderm which become confluent to form the *intra-embryonic cœlom.* The cells of the lateral plate mesoderm differentiate to form the connective tissues of the body with the exception of those developed from the sclerotome, the lining mesothelial cells of the peritoneum, pleuræ and the pericardium, and the plain muscles of the alimentary canal and the blood vessels.

The lateral plate mesoderm is continuous with the paraxial mesoderm at its ventrilateral angle and does not show any sign of segmentation. The narrow strip of mesoderm that connects the paraxial mesoderm with the lateral plate mesoderm

is called the *intermediate mesoderm* which later on gives rise to the formation of the excretory system and the gonads. The lateral plate mesoderm of each side extends forwards in front of the somite region and usually fuses together in the middle line in front of the prochordal plate. The mesoderm of bilateral origin in front of the prochordal plate gives rise to the formation of heart and hence called the *procardiac mesoderm.* The intra-embryonic cœlom of either side is continuous with each other in front of the procardiac mesoderm and forms a single horse-shoe-shaped cavity. The intra-embryonic cœlom is at first a closed space but later on it communicates with the extra-embryonic cœlom at the lateral edge of each of its caudal extremities. Thus the intra-embryonic cœlom formed by the intra-embryonic mesoderm intervenes between the ectoderm dorsally and the entoderm on the ventral aspect. The mesoderm lining the intra-embryonic cœlom on the ectoderm is called the *intra-embryonic somatopleuric mesoderm* or *somatic mesoderm* and together with the ectoderm it constitutes the *somatopleure;* and that lining the intra-embryonic cœlom on the entoderm is called the *intra-embryonic splanchnopleuric mesoderm* or *splanchnic mesoderm* and together with the entoderm it constitutes the *splanchnopleure.*

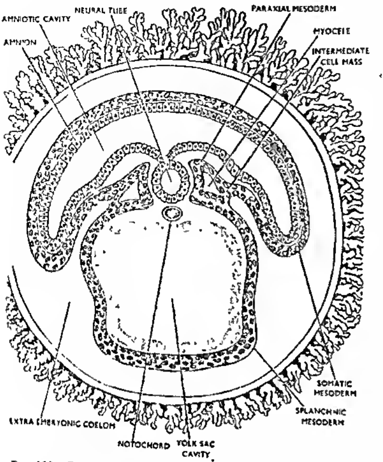


Fig. 133 Diagrammatic representation of a transverse section of the embryo to show neural tube, notochord and part of the secondary mesoderm.

INTRA-EMBRYONIC CŒLOM

The intra-embryonic cœlom is a horse-shoe-shaped cavity within the embryo and is formed by the confluence of initially isolated cavities in the lateral plate mesoderm. At first, it is a closed cavity but later on, it communicates with the extra-embryonic cœlom laterally at its caudal end on each side. As it is a horse-shoe-shaped cavity it consists of a transverse limb which joins the anterior ends of the two longitudinal limbs. The transverse limb of the intraembryonic cœlom passes transversely across the middle line in front of the prochordal plate or the bucco-pharyngeal membrane and forms the primitive pericardium which contains the cardiogenic plate in its floor. With the folding of the head and tail ends, the primitive pericardium is carried ventrally and caudally and the cardiogenic plate which was originally placed in the floor of the pericardial cavity now comes to occupy the roof of the same. With subsequent reversal of the head fold, the mesoderm, which

was lying ventro-cranially, is displaced caudally. This caudally placed mass of mesoderm is now called the *septum transversum.* The longitudinal limbs of the intra-embryonic cœlom are now called the *pericardio-peritoneal canals.* With subsequent growth, these canals are lengthened and the growing lungs are invaginated into them. The cranial segments of the pericardio-peritoneal canals opposite the lung-buds are called the *pleural cavities* and the caudal segments form the *peritoneal cavity.* Now at this stage the intra-embryonic cœlom can be differentiated into a median pericardial cavity, two pleural cavities and the peritoneal cavity. The pericardial cavity communicates on each side with the pleural cavity by the pleuro-pericardial openings and then each of the pleural cavities communicates with the peritoneal cavity by *pleuro-peritoneal opening.* Later on, these openings of communication become completely obliterated and the pleural cavities are separated from the pericardial cavity by the duct of Cuvier and from the peritoneal cavity, by further development of the diaphragm. The communication between the extra-embryonic and the intra-embryonic cœlom is also obliterated.

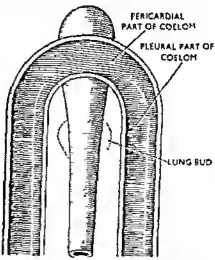


Fig. 134. Pleuro-pericardial parts of the cœlom together with the primitive pharynx and the lung-bud.

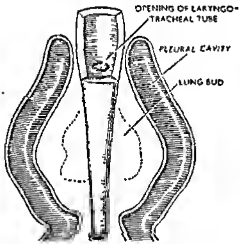


Fig. 135. The pleuro-peritoneal cavities.

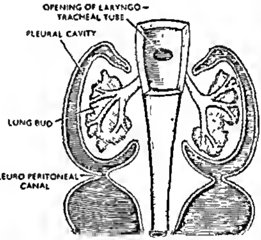


Fig. 136. A further stage of figure 135.

FATE OF THE GERMINAL LAYERS

Ectodermal derivatives—

(1) Epithelium of the skin and its appendages such as hairs, nails, epithelial cells of the sweat, sebaceous and the mammary glands.
(2) Epithelium of the oral and nasal cavities.
(3) Epithelium of the terminal parts of the genital tract, urethral tract and the lower part of the anal canal.
(4) Dental sac of the milk teeth and the enamel of the permanent teeth.
(5) Rathke's pouch which gives rise to the formation of the anterior lobe of the pituitary gland.
(6) Central, peripheral and autonomous nervous systems.
(7) Medulla of the suprarenal glands and the neurilemma sheath of nerves.
(8) Lens of the eye, anterior epithelial layer of the cornea and the outer cuticular layer of the tympanic membrane.
(9) Muscles of the iris.
(10) Sensory epithelia of the auditory and olfactory organs.

Mesodermal derivatives—

(1) All the connective tissues including bones, cartilages, dentine and blood.
(2) Myocardium of the heart and all other muscles in general except the muscles of the iris.
(3) Lymph glands, spleen and the lymph vessels.
(4) Endocardium and the endothelial lining of the blood vessels.
(5) Bursæ and the synovial membranes of the joints.

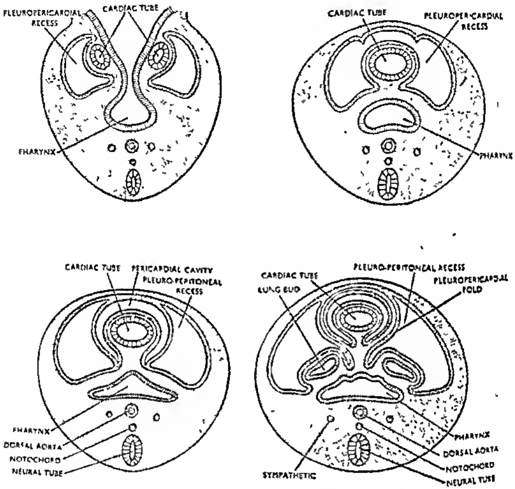


Fig. 137. The four figures above are transverse sections of embryo (Diagrammatic) to show the development of the pericardial cavity.

Entodermal derivatives—

(1) The epithelium covering the whole of the alimentary tract except its terminal parts.
(2) Parenchymatous tissues of the liver, pancreas, thyroid, parathyroid and the thymus gland.
(3) Epithelium covering the larynx, trachea, bronchi and the lung alveoli.
(4) Epithelium of the tympanic cavity including the inner surface of the tympanic membrane and the epithelium of the pharyngotympanic tube.
(5) Epithelium of the urinary bladder except that over the trigone of the bladder which is of mesodermal origin.
(6) Epithelium of the urethral canal except its terminal part and the epithelium of the upper part of the vagina.
(7) Prostate gland in case of male.

FŒTAL MEMBRANES

Roughly speaking, any tissue that develops from the fertilised ovum and does not come to the formation of any part of the fœtus proper, is known as the *fœtal membrane.* The *yolk sac*, the *allantois*, the *amnion*, the *chorion*, and the *umbilical cord*, all these structures constitute the *fœtal membranes* as they do not come to the construction of the fœtus proper. Before the formation of the chorion and the amnion the *outer trophoblastic layer of a blastocœle is the first fœtal membrane.* It is partly separated from the inner cell-mass by the blastocœle containing fluid. The trophoblastic layer is ectodermal in origin and forms the first unilaminar fœtal membrane.

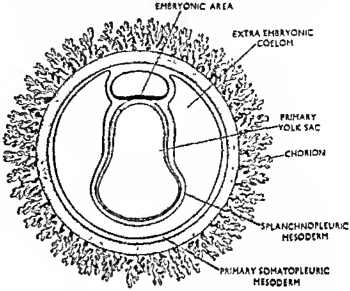


Fig. 138. A schematic section of the embryo to show the primary yolk sac.

The Yolk Sac. It has already been stated that after the formation of the blastocœle a layer of entodermal cells segregate from the inner cell mass and lines the inner aspect of the trophoblast, and thus the unilaminar trophoblast becomes bilaminar, and consists of inner entoderm and outer ectoderm. The cavity contained within the entodermal lining is the *primary yolk sac.*

The primary yolk sac consists of a roof, a floor and surrounding walls. Its roof is formed by a layer of extra-embryonic entoderm which is covered by splanchnopleuric mesoderm. Its floor is formed by embryonic entoderm of the embryonic disc. Its surrounding walls are formed by embryonic entoderm and the splanchnopleuric mesoderm. The primary yolk sac then becomes much smaller in size due to detachment of its distal portion. The much reduced proximal portion of the primary yolk sac which now exists, is called the *secondary yolk sac.* The isolated detached portion of the primary yolk sac then gradually disappears. The cavity enclosed by the somatopleuric and splanchnopleuric mesoderm is called the *extra-embryonic cœlom* which now [illegible] much enlarged.

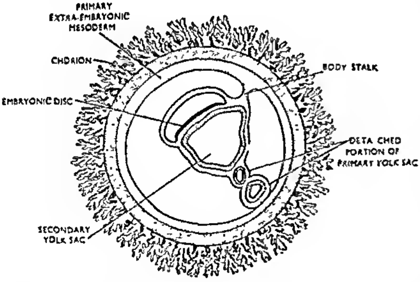


Fig. 139. A further stage of figure 138.

The splanchnopleuric mesoderm which lines the outer aspect of the sec-

yolk sac gives rise to the formation of islands of blood vessels which later on unite together and form an extensive network of blood vessels on the outer aspect of the secondary yolk sac. The vessels from the latter form a pair of vitelline veins and arteries which, by process of extension, communicate with the vessels within the embryo. Concurrently with the process of vascularisation of the secondary yolk sac, a diverticulum, the *allanto-enteric diverticulum*, extends from the tail end of the secondary yolk sac.

After the allanto-enteric diverticulum has been formed the embryonic portion of the secondary yolk sac gets partially entangled within the rapidly growing embryo. The rapidly growing embryo which bulges out into the enlarging amniotic cavity and now differentiates into head, tail and lateral folds. The portion of the secondary yolk sac entangled within the head fold is called the *foregut*, that within the tail fold is called the *hindgut* and the remaining portion that intervenes between them is called the *midgut* which at this stage, is represented mostly by the secondary yolk sac. The portion that bulges out from the embryo is now called the *definitive yolk sac*.

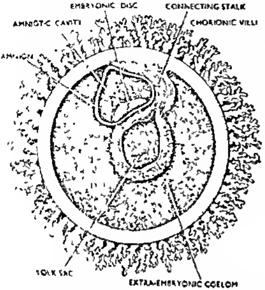


Fig. 140. Diagram to show the extra-embryonic coelom, amniotic and yolk sac cavities and the body stalk.

With further development the embryo increases in size and the intestinal tract elongates; and with the elongation of the intestinal tract the communication between the midgut and the secondary yolk sac becomes much reduced and the narrowed path of communication, that now exists, is called the *vitello-intestinal duct* or *vitelline duct*. With still further growth, the amniotic cavity and the vitelline duct elongates and the secondary yolk sac is gradually absorbed into intestinal tract and is removed from the body wall. The vessels of the yolk sac are the vitelline vessels. The vitelline arteries arise from the dorsal aorta and later on are fused to form the *superior mesenteric artery* which is the artery of the midgut. The vitelline veins like the umbilical veins undergo changes and are entangled within the developing liver.

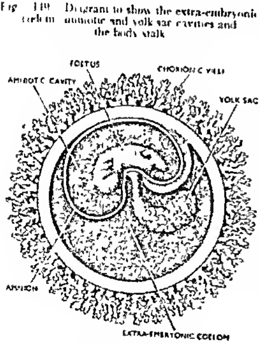


Fig. 141. A further stage of figure 140.

Note the extension of amniotic cavity at the expense of the extra-embryonic coelom.

The allantois. It first appears as a diverticulum from the tail end of the secondary yolk sac and is known as the *allanto-enteric diverticulum*. Compared to other mammals, the human allantois is rudimentary in size and does not evaginate into the extra-embryonic coelom. It grows out in the mesenchyme of the

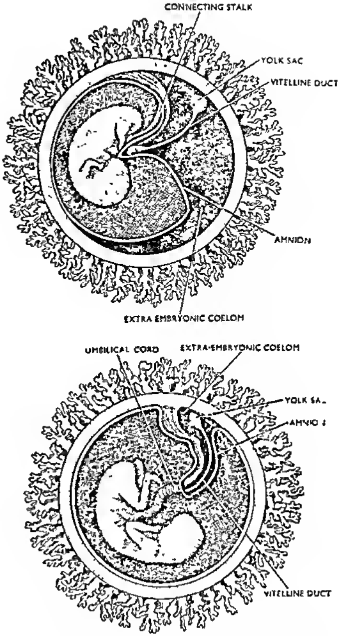


Fig. 142. The two figures above are further stages of figure 141 and show the gradual obliteration of the extra-embryonic cœlom by the extension of the amniotic cavity and the formation of the umbilical cord.

connecting stalk and extend as far as the chorion. The allanto-enteric diverticulum together with the connecting stalk constitutes the *body stalk* from which the umbilical cord develops. Thus in the growing umbilical cord it forms one of its components and is as long as the cord itself.

With the formation of the head and tail folds, the hindgut moves ventralwards, and the allanto-enteric diverticulum, which was originally attached to the tail end of the secondary yolk sac, is found to be attached to the ventral aspect of the hind-gut.

The allanto-enteric diverticulum which has now been connected to the hind-gut, and has been separated from the secondary yolk sac, is called the *definitive allantois.* The dilated portion of the hind-gut caudal to the attachment of the allantois is called the *entodermal cloaca.*

The allantoic blood vessels develop in situ in the mesoderm of the body stalk and give rise to the formation of a pair of umbilical veins and arteries which grow in both directions and vascularise the chorion at one end and establish communication with the blood vessels of the embryo at the other end.

Fate of allantois. During the later stage of development the growth of the allantois ceases altogether and it becomes obliterated, fragmented and ultimately disappears completely.

The amnion. It has already been stated that the ectodermal cells of the
i become condensed to form the embryonic disc which separates
iner aspect of the trophoblastic cells opposite the central part, but
ed to the latter at its periphery. Thus, a cavity is formed between
lisc and the inner layer of the trophoblastic cells which is known as
ity. The inner layer of the trophoblastic cells opposite the em-
n differentiate into *amniogenic cells.* With the growth and extension
bryonic mesoderm, the amniogenic layer is gradually separated from the trophoblastic cells except at the region adjoining the caudal part of the embryonic disc where the amnion, the caudal end of the embryonic disc and the inner aspect of the chorion remain fused together. The fused caudal end of the

bryonic disc together with the amnion and the chorion now forms the *body stalk* which later on develops into the umbilical cord.

As stated above the amnion remains connected to the periphery of the embryonic disc which forms the floor of the amniotic cavity while its roof being formed by the amnion itself. With the growth of the embryonic disc and formation of the embryo, the line of attachment of the amnion moves to the ventral body wall and gradually becomes smaller until ultimately it bounds the umbilical region and the amnion forms an investment for the developing umbilical cord. Concurrently with the above changes the amniotic cavity rapidly enlarges at the expense of the extra-embryonic cœlom and ultimately completely obliterates the extra-embryonic cœlom except close to the placental end of the cord where a narrow cleft exists between the latter and the vitelline duct. The amnion then blends with the mesoderm of the chorion and the two membranes are fused to form a single layer.

Structurally the amnion forms a thin, transparent non-vascular membrane which is composed of a single layer of ectodermal epithelium and is lined externally by the mesodermal connective tissue.

The amniotic fluid. The amniotic cavity contains the amniotic fluid formed, at first, either by filtration or by secretion from amniogenic cells, and lately, when the *fœtal kidney begins to function some of its urine is* also added to it. *The amniotic* cavity is a closed sac except during the early stage when it communicates with the yolk sac through notochordal or neurentric canal. The total amniotic fluid at birth measures about three pints in quantity. In some pregnancies this fluid may be much reduced in amount giving rise to a condition known as *oligoamnios.* The reduced quantity of the amniotic fluid may indicate either the absence of the functional kidney or obstruction in the urinary tract. It is known that during later part of pregnancy the amount of the amniotic fluid is reduced to some extent, and its reduction is substantiated by the fact that during later part of pregnancy the baby swallows some quantity of the amniotic fluid which is absorbed from the intestine of the fœtus and then circulates in the fœtal blood and subsequently passes to the mother by way of the placenta. An increase in the amount of the fluid either due to increased production or decrease in its absorption leads to a condition known as the *hydramnios.*

CHORIONIC VILLI AND EARLY PLACENTA

The chorion, which consists of two layers, ectodermal trophoblast and the primary extra-embryonic mesoderm, undergoes rapid proliferation to form a chorionic vesicle. At this stage the trophoblastic layer of the chorion is rapidly proliferating and can be divisible into two parts, *outer plasmoditrophoblast* or *syncytial layer,* and *inner cytotrophoblast.* Owing to extremely rapid proliferation the cellular outline in the syncytial layer is no longer detectable and the whole layer appears to be a protoplasmic mass with innumerable nuclei. As the syncytial layer proliferates it burrows through the maternal tissue and as a result, some of the maternal blood spaces become opened. Due to rapid proliferation spaces are also formed within the syncytial layer known as the *lacunæ.* The lacunæ at the syncytial layer of the trophoblast is filled with maternal blood, which upto this

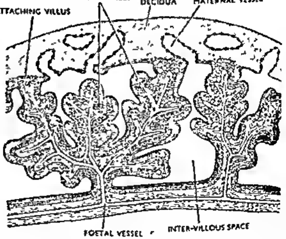


Fig. 143. Secondary chorionic villi

stage, is a source of nutrition to the embryo and reaches it by the process of diffusion. Later on, simple circulatory system develops within the embryo, the connecting stalk, the yolk sac and within the chorion. The changes that lead to the vascularisation of the chorion result in the formation of the *chorionic villi* and are described below:

(*a*) The cytotrophoblast or the inner layer of cells of the trophoblast protrudes into the syncytial trabeculæ in between its lacunæ. The core of cytotrophoblast within the syncytium is called the *primary villus.* The lacunæ on either side of the primary villi become confluent with each other to form a continuous intervillous space which is filled with maternal blood.

(*b*) The mesodermal lining of the trophoblast follows the trophoblastic protrusions and forms a core of mesodermal tissue within the primary villi and thus gives rise to the formation of the *secondary villi.* The mesodermal core of the secondary villi then gives rise to the formation of arterio-capillary-venous system within each villus and subsequently these circulatory systems within the villi are linked with the fœtal heart by blood vessels growing in the mesenchyme of the connecting stalk and the inner aspect of the chorion. Now the villi with arterio-capillary-venous systems which have established connections with the fœtal heart are called the *tertiary* or *definitive villi.*

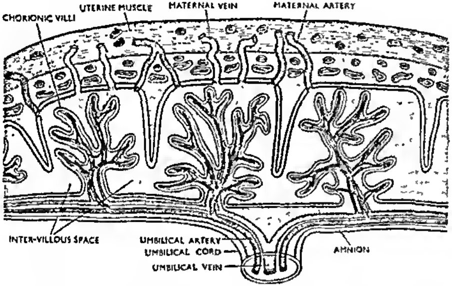


Fig. 144. A schematic diagram to show the placental circulation

The chorionic villi surround the whole circumference of the chorionic vesicle but those opposite the decidua capsularis fail to develop properly due to lack of nutrition while those opposite the decidua basalis develop enormously in the presence of sufficient nutrition derived from the opened up maternal blood-spaces. At certain points the cytotrophoblastic core penetrates through the syncytial mass and comes out of it to lie in direct contact with the maternal decidua and these columns of cells are called the *trophoblastic shell.* The trophoblastic shells are destined to anchor some of the main villi into the maternal tissue and hence they are also called the *anchoring villi.* Besides the anchoring villi there are numerous short-branched villi which remain free and do not come into contact with the decidua. Except opposite the anchoring areas the cytotrophoblast now forms a single layer of cells and intervenes between the outer syncytial layer and the inner mesodermal core. This mode of structural arrangement of the villi exists up to the third month of fœtal life but from the fourth month onwards, of the two layers of the trophoblasts (cytotrophoblastic and syncytial layers) the cytotrophoblast begins to disappear, and from the fifth month, it is the syncytial layer that only exists. The mesodermal core of the anchoring villi never penetrates through the covering cytotrophoblast and consequently, the

fœtal blood vessels derived from the core, do not come into contact with the maternal decidua or the maternal blood. Thus it shows that the fœtal blood or blood vessels are separated from the maternal blood or blood vessels by the intervening trophoblastic layers. With the subsequent growth of the placenta, the distal portions of the anchoring villi and the proximal portions of their distal branches become fused with the maternal decidua. This can be explained by the fact that the anchoring villi penetrate deep into the decidua away from the uterine cavity where it gives out its distal branches which project sidewards and then curve to project towards the uterine cavity into the maternal blood sinuses. Thus these distal branches of the anchoring villi will be seen to be projecting from the maternal side of the sinuses.

With the further growth of the placenta the chorionic villi towards the decidua basalis become enlarged and branching and they form collectively what is known as *the chorion frondosum* while those opposite the decidua capsularis become degenerated and atrophied and as a result, the villi opposite the decidua capsularis present a smooth surface and are devoid of any blood vessels, and this part of the chorion is called the *chorion læve.*

THE PLACENTA. The placenta at term is an irregularly round organ which develops temporarily during pregnancy and is expelled out with the termination of the same (pregnancy). It is a spongy highly vascular body which is connected with the fœtus by the umbilical cord and with the maternal tissue by villous processes and is a specially designed organ of exchange between the mother and the fœtus during intra-uterine life.

Size. The size is variable, and usually with large babies, the size becomes comparatively larger. It measures about 15 to 18 cm. in diameter and in thickness, it is about 1½ to 3 cm. in its thickest part, that is, opposite the central region of the organ. Towards the periphery it becomes gradually thinner

Form. In form it is irregularly round in the normal condition, but depending on the site of its insertion on the uterus, it may assume any form.

Weight. It weighs about 500 grams at full term and the ratio between it and the fœtus is 1 : 6.

Colour and consistence. It is dark-red in colour and is of soft friable consistence.

Parts for examination. It consists of a fœtal surface, a maternal surface and a circumferential border.

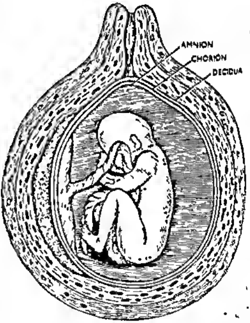


Fig. 145. A section through the uterus with the fœtus and the placenta in position

Fœtal surface. The fœtal surface is that surface of placenta in which the umbilical cord is inserted. It presents a smooth glistening appearance due to the amnion which forms a close investment over this surface. The amnion can be easily separated from this surface except close to the Wharton's jelly. Blood vessels spreading in all directions from the site of attachment of the cord can be seen through the transparent amnion. Within a distance of about ½" inch from the peripheral margin, the blood vessels are not usually seen because the terminal twigs at this space pass deeper into the substance of the organ. On close inspection small whitish-yellow spots of fibrous tissue can be seen to spread over this surface and they indicate the sites of formations of the white infarcts. The umbilical cord is usually inserted into the centre of this surface but its attachment varies considerably from case to case.

Maternal surface. The maternal surface presents a rough lobulated appearance due to decidual septa dividing this surface into several lobes. The lobes are called *cotyledons.* This surface is covered by a thin greyish-white membrane which is formed by the substantia compacta of the decidua basalis. When the placenta comes out, the decidua compacta being adherent to the maternal surface of the placenta, separation takes place through the spongy layer of the decidua.

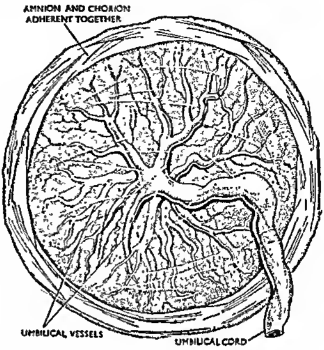


Fig. 146. Foetal surface of a normal placenta.

Membranes. The bag of membrane that overhangs from the placenta usually goes by the name "membranes". It is formed by the chorion læve and amnion. The outer layer is formed by the chorion which is thicker, opaque and friable and on its maternal surface the decidua vera and capsularis are attached. The inner layer is formed by the amnion which is tough and transparent. The membrane presents an opening through which the baby made its way out and this opening normally is about 10 cm. from the margin of the placenta. In case of lower insertion of the cord this distance is proportionately reduced. Thus in placenta prævia this distance is considerably reduced.

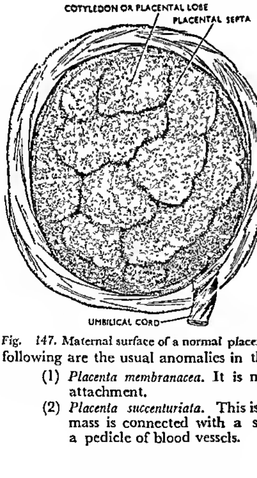


Fig. 147. Maternal surface of a normal placenta.

Developmental anomalies: (A) ANOMALY OF FORM. Depending on the site of embedding of the fertilised ovum in the uterus the form and shape of the placenta may be considerably altered. Thus when it is attached close to the lateral angle of the uterus, the decidua being comparatively thin in this part, the placental attachment spreads out either in the fundus or in the body or to both and thereby these extensions of attachment reflect on the character of individual lobes. Similarly if the ovum is attached lower down in the lower uterine segment the placenta may cover an wide area of attachment. Pathological growth of fibrous tissue within the placenta may also split it into lobes. The following are the usual anomalies in the form of the placenta:

(1) *Placenta membranacea.* It is membrane-like and acquires an wider area of attachment.

(2) *Placenta succenturiata.* This is a form of placenta where the main placental mass is connected with a small separate accessory placental mass by a pedicle of blood vessels.

(3) *Placenta spuria.* This form of placenta differs from the above in that the accessory placental mass is connected with the main mass by a membrane and not by a pedicle of blood vessels.
(4) *Bilobed placenta or placenta bi-partita.* Having two lobes.
(5) *Trilobed placenta.* Having three lobes.
(6) *Horse-shoe placenta.* Having the shape of a horse-shoe.

(B) Anomaly of Attachment of the Umbilical Cord. Normally the umbilical cord is attached to the centre of the fœtal surface of the placenta. The following anomalies are usually noticed :-

(1) *Marginal insertion.* Instead of being attached in the centre, the cord may be attached to the margin. This form of placenta with marginal attachment of the cord is called the *battledore placenta*.

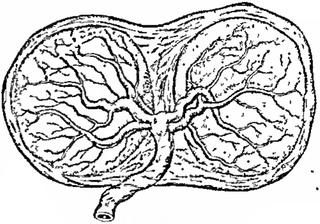


Fig. 148. Placenta bi-partita.

(2) *Velamentous insertion of the cord.* In this the cord is attached to the membrane adjacent to the placenta.

Structure of Placenta. A section through placenta is seen to consist of amnion and chorion externally (towards the fœtal surface) and the compact layer of the decidua internally (towards the the maternal surface). In between these two layers it consists of continuous blood-spaces containing innumerable red blood corpuscles in which islands of divided fœtal villi and fibrous trabeculæ of various shape and size are seen to project. Each villus consists of a core of jelly-like connective tissue (Wharton's jelly) which is surrounded by a syncytial layer of epithelium. In the Wharton's jelly blood vessels may be present in the form of arterioles, venules or capillaries.

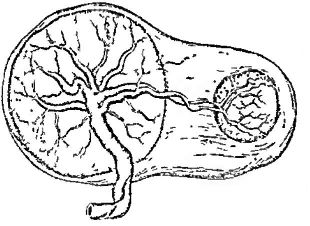


Fig. 149. Placenta succenturiata.

Functions of Placenta. It serves as the external respiratory organ for the fœtus.

Food materials of the maternal blood pass through it into the blood stream of the fœtus.

It transmits the waste products of the fœtal blood into the maternal blood.

It acts as a barrier against infection of some diseases and thus protects the fœtus from such infections.

It produces two ovarian hormones namely, œstrogen and progesterone, which help to continue pregnancy and to develop the mammary glands. It also produces chorionic follicle stimulating and luteinizing hormones.

To summarise, the placenta serves as lungs, alimentary canal, kidneys and partly as reticulo-endothelial system and as a barrier against infection for the fœtus.

it also provides hormones to the mother as mentioned above. It is also permeable to the substances as mentioned below.

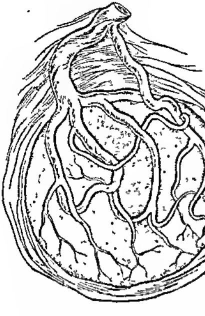


Fig 150. Velamentous insertion of the cord.

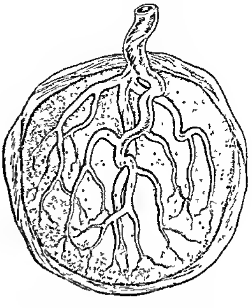


Fig 151. Battledore placenta.

Permeability of Placenta in Man. *Nutritive Element.* Maternal blood sugar level is higher than that of the fœtus and it passes unaltered through the placenta into the fœtus. Protein molecules cannot pass through the placental barrier to the fœtus. Amino-acids concentration of fœtal blood is however higher than that of the maternal blood and the fœtus builds its proteins from the amino-acids. It is not definitely known about the means of transfer. Phospholipoids and cholesterol pass through the placenta unchanged to the fœtus.

Minerals and Vitamins. Soluble minerals and vitamins usually pass through the placenta unchanged. The mode of iron absorption is however different. The R. B. C's of maternal blood undergo hæmolysis in the placenta by the activity of the trophoblastic cells and the product of disintegrated hæmoglobin are transmitted through the placenta to the fœtus in which the hæmopoietic tissues re-synthesize them into hæmoglobin.

Antitoxins, Antibodies and Hormones. Antitoxins and agglutinins such as Rh-antibodies pass through the placenta. Maternal hormones such as thyroxin, insulin and œstrogens are transmitted to the fœtus.

Drugs. Most of the organic substances, anæsthetics, barbiturates, morphine and related alkaloids, sulphonamides and penicillin pass through the placenta to the fœtal blood.

THE UMBILICAL CORD. The body stalk, formed by the fusion of the caudal end of the embryonic disc, the amnion and the chorion, gives rise to the formation of the umbilical cord. At first the body stalk is attached to the caudal end of the embryonic disc but with the growth of the disc and enlargement of the embryo it moves ventralwards. The body stalk then rapidly elongates to form the umbilical cord, and the extra-embryonic primary mesoderm and the secondary mesoderm from the caudal end of the embryo constitute the structural basis of the umbilical cord. The umbilical cord receives a tubular sheath from the amnion which is lined with somatopleuric mesoderm. The vitelline duct and the body stalk are lined with splanchnopleuric mesoderm and the two mesoderms fuse together except where the cleft of the extra-embryonic cœlom exists.

The mesodermal core of the umbilical cord gives rise to the formation of a pair of umbilical veins and arteries and later on, by degenerative changes forms a jelly like mesenchyme (Wharton's jelly which has no vessels or nerves) through

which the umbilical vessels, the vitelline duct and the allanto-enteric diverticulum pass. One of the veins soon disappears and normally during mid-pregnancy the vitelline duct with its vessels and the enclosed extra-embryonic cœlom of the cord also disappear. The extra-embryonic portion of the allantois disappears at full term while its intra-embryonic portion forms the *urachus* which extends from the apex of the bladder to the umbilicus.

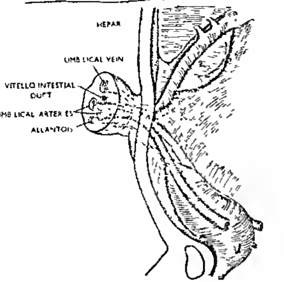


Fig. 152 Sagittal view of a reconstruction of the umbilical region of a human embryo 5·5 cm. in length (after Callen).

With kind permission From Callander: Surgical Anatomy, 2nd ed 1939. W B Saunders Company, Philadelphia and London.

—During the early embryonic life the umbilical cord is very short but during the later part it elongates rapidly to a considerable extent. At birth its average length is about 20 inches but it may vary from four to sixty inches. A too short cord may cause a difficult labour while too long a cord may cause prolapse of the same or it may encircle round the neck of the fœtus.

MOUTH, NASAL CAVITY AND PALATE

The earliest rudiment of the mouth is an ectodermal pit known as the *stomodæum, oral pit* or the *primitive mouth* which intervenes between the overhanging forebrain and the pericardial swelling. Above the margin of the primitive mouth at this stage, on either side of the median plane, proliferation of the ectoderm results in a convex ectodermal thickening known as the *nasal placodes*. Subsequently, the visceral arches appear, and during late somite stage, they grow up considerably to intervene between the pericardial swelling and the primitive mouth. The first visceral or the mandibular arch becomes more prominent than the others, comes to lie on the floor of the growing stomodæum and from its dorsal end it gives out the *maxillary process* which lies below the optic vesicle and grows out ventro-medially to form the lateral boundary of the stomodæum. The mesodermal tissue between the stomodæal ectoderm and the growing forebrain grows down considerably as a median process known as the *fronto-nasal process* which now forms the roof of the growing stomodæum. Thus, during late somite stage, the stomodæum is seen to be bounded above by the fronto-nasal process, below by the mandibular arch and on either side by the maxillary process. At this stage the foregut diverticulum has considerably extended cranialwards and its cranial end comes to lie in apposition with the deep part of the oral pit which is separated from the former by a membrane known as the *buccopharyngeal membrane*. From the roof of the oral pit, just in front of the buccopharyngeal membrane, an ectodermal diverticulum extends cranially to the hinder aspect of the forebrain and this diverticulum is called the *Rathke's pouch* from which, subsequently, the glandular part of the pituitary body is developed. At about 20 somite stage the buccopharyngeal membrane ruptures and the foregut entoderm becomes continuous with the ectoderm of the stomodæum and thus the foregut is communicated to the oral pit.

With further growth, a localised pit, the *olfactory pit* appears on each of the nasal placodes due to invagination of the thickened ectoderm. The olfactory pit then enlarges and extends into the stomodæal margin and opens into the stomodæal pit. Thus the fronto-nasal process, which formed the upper boundary of the stomodæum, subdivided into lateral and medial nasal folds or processes by the olfactory pit on each side of the median plane. The two medial nasal folds or processes, one on

each side of a median depression, are continuous with each other, and seen together, they form as if a median process on either side of which there lies the corresponding olfactory pit. The caudal end of each of the medial nasal process becomes globular and is known as the *globular process*. With further growth both the lateral and medial nasal processes gain in bulk and the growing maxillary process projects ventromedially across the open end of the olfactory pit and divides the latter into *anterior* and *posterior primitive nares*. The maxillary process then extends further medially and joins with the globular process and thus the upper margin of the outer opening of the oral pit is completed and the olfactory pit is isolated from the stomodæal margin. According to some authority the maxillary process not only joins with the medial nasal process but it crosses superficially its lower part to meet the fellow of its opposite side in the median plane. The lower deep portion of the globular process on either side then grows out dorso-laterally caudal to the posterior nare and forms the *primitive palate*. The nasal pits now have become *primitive nasal cavities* which are separated from each other by the deep aspect of the globular processes which form the *primitive nasal septum*.

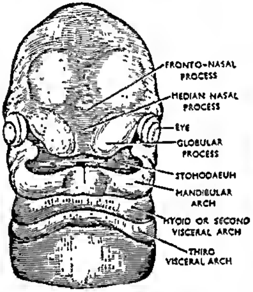


Fig. 153. Development of human face.

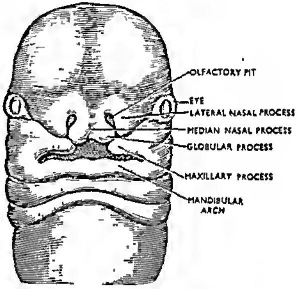


Fig. 154. Development of human face. A further stage of figure 153.

With further growth the primitive nasal cavities extend dorso-cranially and the primitive nasal septum is compressed between the extending nasal cavities to form a thinned out partition, the *definitive nasal septum* whose caudal free border lies in contact with the dorsum of the developing tongue. The nasal cavities are now separated from each other by the definitive nasal septum but their floor, except in the region of the primitive palate, remains open on the roof of the mouth. Subsequently the mesoderm of the maxillary process forms two shelf-like projections, one on each side, known as the *palatal processes* which at first lie in the same level with the tongue and come to lie in contact with its margins. Later on with further growth, the mandibular arch being moved in the caudal direction, the developing tongue is also carried caudally along with it and the palatal processes are freed and they come to lie on a higher level than the tongue. Subsequently, the palatal processes grow transversely inwards until they meet and fuse together in the median plane, the fusion usually taking place from before backwards. Ventrally they fuse with the primitive palate and cranially they fuse with the ventral ¾ of the free edge of the nasal septum in the median plane; the remaining ¼ of the dorsal part of the nasal septum forms the posterior free border of the nasal septum. Subsequently, each palatal process grows dorsally along the side wall of the pharynx

and then medialwards to meet and fuse with the fellow of its opposite side in the median plane and thus the soft palate and the uvula are formed. With the formation of the palate the stomoduæm which communicates dorsally with the primitive pharynx is divided into upper nasal cavities and lower buccal cavity, both of which communicate dorsally with the pharynx.

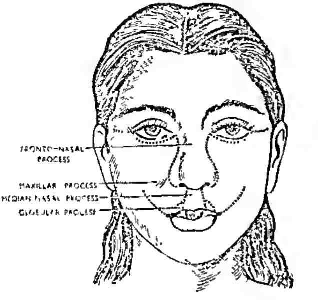


Fig 155 Adult human face to show the fusion lines.

Parts derived from the primitive stomodæum. The primitive stomodæum is an ectodermal pit which intervenes between the overhanging forebrain and the pericardial swelling. Until fifth week of fœtal life it is separated from the primitive pharynx by the buccopharyngeal membrane and in front of the dorsal margin of the membrane the stomodæal ectoderm sends out an evagination upwards and backwards into the hinder part of the forebrain known as the *Rathke's pouch* from which subsequently the glandular part of the pituitary body is developed. Thus the dorsal boundary of the stomodæum is formed by the buccopharyngeal membrane which separates it from the primitive pharynx and consequently all the structures developed in front of this membrane are derivatives of the stomodæum. In addition to *Rathke's pouch*, *lips*, *teeth*, *hard palate* and *anterior part of the soft palate* develop in front of the buccopharyngeal membrane and consequently they are derivatives of the stomodæum. To summarise, the glandular part of the pituitary body, lips, teeth, hard palate and the anterior part of the soft palate are derived from the stomodæum.

Structures derived from the medial nasal processes. It has already been stated that the medial nasal processes together form a central process on either side of which there lies the corresponding nasal aperture. They are separated from each other by a median groove which gradually deepens caudally. On either side of the median plane each medial nasal process becomes globular to form the *globular process* which diverges from each other caudally. If we divide each globular process into three zones, the superficial one is seen to form the philtrum, the deep one, the nasal septum and the premaxillary part of the hard palate, and the intermediate one, forms the medial part of the premaxilla carrying the medial incisors (lateral portion of the pre-

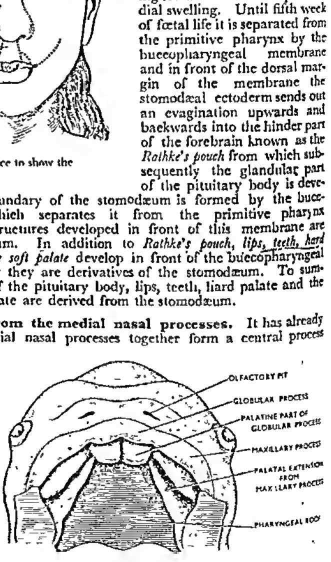


Fig. 156. Roof of the mouth cavity to show the development of the palate.

maxilla being derived from the maxillary process). Given below are the structures derived from the medial nasal processes.

1. Premaxilla carrying the two medial incisors.
2. Premaxillary part of hard palate.
3. Nasal septum.
4. Philtrum including the frenum of the upper lip. (According to some only the deep part of the philtrum is formed from the medial nasal processes).

Vessels and nerves associated with medial nasal processes. The vessels supplying the medial nasal processes are the sphenopalatine and the anterior ethmoidal, and the nerves are nasal and sphenopalatine.

Parts derived from the lateral nasal process. The following structures are formed in the cartilage of the lateral nasal process :

(1) The cribriform plate and the lateral mass of the ethmoid.
(2) Inferior nasal concha.
(3) Superior portion of the body of the maxilla including the frontal process.
(4) Lacrimal and the nasal bones.
(5) The lateral cartilage of the nose and a part of the alar cartilage of the nasal septum.

Vessels and nerves associated with the process. The vessels of the lateral nasal process are the anterior ethmoidal and descending palatine.

The nerves are derived from the Meckel's ganglion, descending palatine and the nasal nerves.

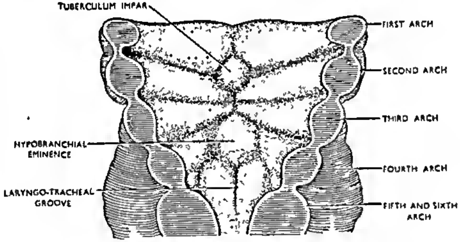


Fig. 157. Ventral aspect of the developing pharyngeal region.

Parts derived from the maxillary process. The following parts are rived from each maxillary process :

Bones. Part of the body of the maxilla and its alveolar process, lateral part of emaxilla, hard palate except the premaxillary part, zygomatic process of the mporal bone, zygomatic bone, medial pterygoid lamina and the perpendicular ate of the palatine and the greater wing of the sphenoid (the last three being rived from the palatoquadrate bar).

Soft parts. Upper lip including the superficial portion of the philtrum (according to some, upper lip except the philtrum), muscles of the cheek and soft palate.

Vessels and nerves. The internal maxillary artery is the main vessel while the cond division of the fifth nerve (Maxillary) is the main nerve.

Floor of the mouth. The ventral ends of the pharyngeal arches and grooves ass towards the median plane and the first and the second arches meet with the fellow of their opposite side in the median plane. A median eminence, the *tuberculum impar* soon appears caudal to the fused anterior end of the first pharyngeal arches. The

second pharyngeal arch of one side becomes continuous with the fellow of its opposite side in the median plane and forms a continuous arch. Another median eminence, the *hypobranchial eminence* intervenes between the anteroir ends of the third and the fourth pharyngeal arches and consequently they do not meet in the median plane. Caudal to the hypobranchial eminence, a groove, the *laryngo-tracheal groove*, soon appears and intervenes between the anterior ends of the rudimentary sixth pharyngeal arches. The fifth pharyngeal arches have disappeared by this time. The portion of the fore-gut that lies caudal to the laryngo-tracheal groove forms the *primitive œsophagus*

Thus it is evident that the floor of the buccal cavity, which is covered by both ectoderm and entoderm, is formed by contributions from the first to the fourth pharyngeal arches, and the entoderm of the buccal floor together with the associated ectoderm and mesoderm gives origin to the *tongue*, *epiglottis* and the *sublingual and submandibular salivary glands*. For details see individual organs. The stomodæal ectoderm and the entoderm of the fore-gut are so intermingled in the floor of the buccal cavity that a clear cut demarcation between the two is not manifested well but roughly in the adult the line corresponds to the line of junction between the mandibular gum and the floor of the mouth. In other words, the floor of the adult buccal cavity has entodermal lining while the mandibular teeth and the area in front of it has ectodermal lining and this is substantiated by the fact that the enamel of the teeth is of ectodermal origin.

Lips, cheeks and gums. As is known the first pharyngeal or the mandibular arch ends cranially in a free arched border. An arched groove, the *labio-dental groove*, appears on this free edge of the mandibular arch and subdivides it into ventral and dorsal portions. Another parallel deeper groove, the *linguo-dental groove*, appears on the dorsal portion. The portion of the mandibular arch ventral to the labio-dental groove gives origin to the lower lip, the portion in between the labio-dental and linguo-dental grooves to mandibular gums and the teeth, and the portion dorsal to the linguo-dental groove contributes to the formation of the tongue. The lateral portions of the upper lip are formed similarly from the free lower edge of the maxillary process while its central part is formed by the lower part of the globular process According to Frazer and Boyd the deep portion of the philturm is formed by the lower part of the globular process while its superficial portion is formed by the fused anterior ends of the maxillary processes which cross in front of the fronto-nasal process. Another view holds that the philtrum is formed by the excessive proliferation of the mesoderm derived from the anterior end of the maxillary process on either side of the median plane. The musculature of both upper and lower lips is formed by the second arch mesoderm and consequently it is supplied by the seventh nerve. The cheek is formed by progressive fusion of the upper border of the maxillary process with the infero-lateral border of the lateral nasal process. The muscle of the cheek, that is, the buccinator is formed by the mesoderm of the second pharyngeal arch and consequently it is also supplied by the seventh nerve.

Congenital anomalies affecting the lip. The fusion between the superficial portion of the maxillary process and the lower end of the globular process may be incomplete or partially complete giving rise to different forms of *hare* or *cleft lip* which is often associated with cleft palate. A *mid-line hare-lip* or *true hare lip* may be found due to faulty growth of the lower part of the globular process. *Lateral hare lip* which is more common is due to failure of fusion of the maxillary process with the globular process and may be either unilateral or bilateral. *Oblique facial cleft* may result from complete failure of union of the maxillary process with the lateral margin of the lateral nasal process.

Congenital anomalies affecting the palate. *Cleft palate.* The palatal shelf of the maxillary process of one side fuses with the fellow of its opposite side in the median plane, and anteriorly, they fuse with the primitive palate formed by the deep portion of the globular process. The line of fusion is represented by a Y-shaped outline, the limbs of the Y embracing the two premaxillæ. Varying

grades of failure of fusion may occur giving rise to different forms of cleft palate. Depending on the degree, cleft palate may be either *complete* or *incomplete* which may be either unilateral or bilateral.

Incomplete cleft palate. In this the cleft may affect only the uvula—*bifid uvula* or it may extend to the soft palate as well as to the hard palate.

Complete cleft palate. In complete bilateral cleft palate the cleft is represented by a Y-shaped fissure, the stem of the Y lies posteriorly while its limbs pass along the sides of the premaxillæ and this type of anomaly is usually accompanied by bilateral cleft lip. In the unilateral variety the cleft affects only one side and extends from the lateral margin of the premaxilla upto the uvula and is usually associated with unilateral cleft lip.

Anomalies affecting the cheek. *Oblique facial cleft* usually results when the maxillary process fails to fuse with the lateral nasal process. When the maxillary process fails to unite with the mandibular process there is a deep fissure across the cheek from the region of the ear to the angle of the mouth—*Macrostoma.* This may be either unilateral or bilateral and the extent may vary in degree.

When the fusion between the maxillary and the mandibular processes is too ır advanced the oral aperture becomes too small and the condition is known as *ıicrostoma.*

Anomalies affecting the lower jaw. The lower jaw may also be cleft lue to failure of fusion between two halves of the body of the mandible. 'his may be rudimentary—*microgauthia* or it may be absent altogether—*Aganthia.*

Anomalies affecting the nose. There may be complete absence of the ose or there may be double nose on each side or there may be absence of the nterior nasal aperture.

DIFFERENTIATION OF ALIMENTARY TRACT

With the differentiation of the head and the tail folds the secondary yolk-sac ets partially incorporated within the rapidly growing embryo and its two ends, audal and cephalic, are drawn part into prolongations or diverıcula within the head and the tail olds. The portion included within the head fold is called the *foreut*, that within the tail fold is called the *hind-gut* and the remaining ɔortion that intervenes between hem is called the *mid-gut.*

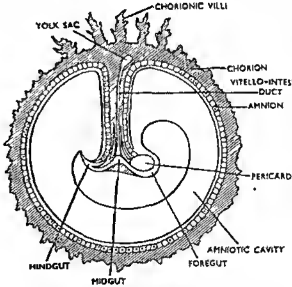


Fig. 158. The developing umbilical cord and the gut tube.

The Fore-gut. It has already been said that with the elongation of the embryonic plate here is alteration in the disposiion of the pericardial and the buccopharyngeal areas resulting n the formation of head and tail folds. The fore-gut is formed as an elongated recess of the secondary yolk-sac lying within the head fold and it is situated between the notochord dorsally and the pericardial region ventrally. The notochord intervenes between it and the neural tube. Cranially the fore-gut ends at the bucco-pharyngeal membrane and caudally it is continuous with that portion of the secondary yolk-sac which later on differentiates into the mid-gut. The portion of the fore-gut which lies dorsal to

the pericardium and is bounded on either side by the cœlomic cavity, constitutes the *primitive œsophagus;* the portion extending into the head fold above the pericardial region constitutes the *primitive pharynx;* as the head fold is bent over the pericardium the latter actually forms the floor of the primitive pharynx; its roof lies related to that portion of the neural canal which forms the hind brain, the notochord and the paraxial mesoderm intervening between the two.

The primitive pharynx. In contrast to the primitive œsophagus the primitive pharynx has no cœlomic cavity on either side of it and as such, the entodermal lining of the primitive pharynx is bounded on either side by the lateral plate mesoderm which is covered externally by the ectoderm. The intervening mesoderm subsequently gives rise to the formation of a series of thickenings known as th *pharyngeal arches* which insinuate themselves between the pharyngeal region and th pericardium and thus allowing independent growth of the region.

The exterior of the primitive pharynx. The exterior of the primitive pharynx i clothed by a layer of ectodermal tissue and is marked by ridges produced by th pharyngeal arches and by the grooves lying in between them. With growth the ex ternal pharyngeal grooves and arches are extensively modified and are describe as follows.

Fate of external pharyngeal grooves. The first external pharyngeal groove, which intervenes between the first and the second pharyngeal arches, disappears almost entirely by extension of growth from the contiguous arches except at its dorsal end where it forms the rudiment of the external auditory meatus. As the pharyngeal arches show marked variation in growth activity the fate of the other external pharyngeal grooves is guided by the said varied growth activity. The first and the second pharyngeal arches grow up disproportionately than the rest of the arches which usually recede. The caudal portion of the second pharyngeal arch grows down as a process which overhangs the remaining pharyngeal arches and grooves and as a result, an ectodermal recess is formed known as the *cervical sinus* which is bounded externally by the down-growth from the second pharyngeal arch, and internally, by the second, third and the fourth external pharyngeal grooves and by the receding third and the fourth pharyngeal arches. Cranially the highest limit of the sinus is formed by the angle of junction of the second external pharyngeal groove and the down-growth from the second pharyngeal arch. Caudally the sinus still communicates with the exterior by a narrow passage known as the *cervical duct.* With further growth the cervical duct is obliterated and the cervical sinus becomes a closed ectodermal vesicle known as the *cervical vesicle.* The main portion of the cervical vesicle lies opposite the third external pharyngeal groove and is in free communication with the second and the fourth external pharyngeal grooves by comparatively narrow clefts known as the "branchial" ducts. With further growth the buried ectodermal vesicle is completely obliterated but occasionally the vesicle persists and gives rise to the formation of a cystic growth known as the *branchial cyst.* Sometimes the cervical duct also persists communicating the sinus with the exterior and at the same time the cleft membrane separating the sinus from the pharyngeal cavity may give way and as a result, the pharyngeal cavity is in communication with the exterior through the cervical sinus and the duct and such a condition is known as *branchial fistula.*

The pharyngeal arches. The pharyngeal arches are five or six in number and cranio-caudally they are named as the mandibular or the first pharyngeal arch, the second pharyngeal arch or the hyoid arch, the third, the fourth and the fifth pharyngeal arches. The fifth arch is very much indistinct and is detectable only on the inner aspect of the pharynx.

The pharyngeal arches are covered internally by the continuous sheet of entodermal lining while externally they are similarly covered by the ectoderm, and on each side in between the pharyngeal arches, grooves are formed both externally as well as internally. The external grooves are known as the *external pharyngeal grooves* while the internal grooves which are deepened considerably on their lateral parts, are

called the *pharyngeal pouches* or ***lateral pouches.*** The intervening tissue between two adjacent pharyngeal arches separates the interior of the primitive pharynx from the exterior and is known as the *separating membrane or "cleft membrane"*. At first the separating membrane is formed by the ectoderm externally and the entoderm internally together with a thin layer of mesoderm intervening between the two. Later on the intervening mesoderm disappears and the separating membrane is formed by the ectoderm and the entoderm only.

They vary in size from before backwards and thus the mandibular arch is the largest of all, the hyoid or the second pharyngeal arch, although very much large at one time, comes next in order, while the succeeding arches gradually diminish in size. Each arch is provided with an artery, a nerve, a muscle rudiment and a skeletal bar which supports it.

The mesoderm of each arch forms the muscular elements as well as the skeletal element of the arch which is cartilaginous. The first or the mandibular arch is well formed and complete and its cartilaginous bar is known as *Meckel's cartilage* from which, later on, the mandible and other skeletal elements develop; the second and the third arches are partly cartilaginous and give rise to the hyoid bone and other skeletal elements while the skeletal elements of the fourth and the fifth arches, which are cartilaginous only at their ventral ends give rise to the formation of the laryngeal cartilages. The arteries of the arches are formed by the aortic arches connecting the dorsal and the ventral aortæ. The chart on page 128 shows the structures derived from the individual arch, and the muscles, vessels and the nerves associated with the arches individually.

The *interior of the primitive pharynx.* It has already been stated that the interior of the primitive pharynx forms pouch-like depressions in between the pharyngeal arches on either side and are known as the *pharyngeal pouches.* As growth proceeds the pharyngeal pouches give rise to the formation of a series of structures enumerated below chronologically : (See also the accompanying table on page 126-128.)

First pharyngeal pouch. The first pharyngeal groove lies between the mandibular and hyoid arches. Its ventral part becomes obliterated with the formation of the tongue. Its dorsal part together with the adjoining portion of the second pharyngeal pouch forms the *tubo-tympanic recess* which gives rise to the formation of the pharyngo-tympanic tube, middle ear and the inner layer of the tympanic membrane.

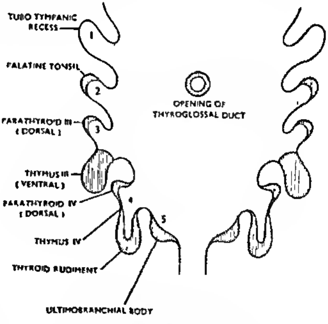


Fig. 159. *The pharyngeal pouches.*

Second pharyngeal pouch. It lies between the second and the third pharyngeal arches. Its ventral portion also gets obliterated with the formation of the tongue. Its dorsal portion forms part of the tubo-tympanic recess and the palatine tonsil. Its lateral portion persists as pharyngeal wall. The ventral portion of its dorsal end on either side, becomes separated from the ectoderm, and the cleft left between the entodermal proliferation and the ectoderm, forms the tonsillar fossa. The connective tissue of the tonsillar fossa later on becomes integrated into tonsils.

Third pharyngeal pouch. It lies between the third and the fourth pharyngeal arches. It gives out bilateral diverticula which later on separate from it and

Visceral Arches and Clefts	Ectodermal Derivatives	Mesodermal Derivatives: Skeletal Elements	Mesodermal Derivatives: Muscle Mass	Entodermal Derivatives	Blood Vessels	Nerves
First Arch or Mandibular arch and cleft.	*Ventral part of arch ectoderm.* Forms—epithelial covering of lingual gum, body of tongue and skin over the future mandible. *Dorsal part of arch ectoderm.* Forms the epithelial covering of the three tubercles of the auricle. *Cephalic part of arch ectoderm.* Forms the labio-dental sulcus and the epithelial lining of the adjoining part of the gum and lower lip; also forms the dental lamina which is burried into the subjacent mesoderm and later on forms the enamel of the teeth of the lower jaw. *Ventral part of first cleft ectoderm.* Obliterates. *Dorsal part of first cleft ectoderm.* Forms the epithelial lining of the external auditory meatus and the cutaneous layer of the tympanic membrane.	*Mandibular arch proper.* Forms the Meckel's cartilage which extends from the cartilaginous ear capsule to the median plane ventrally. Its dorsal part forms the incus and the malleus with its anterior process and part of external ear. Its ventral end is represented by the mental ossicles (?). Its intermediate part disappears but its sheath persists dorsally to form the spheno-mandibular ligament and the anterior ligament of the malleus. The ventral part of the sheath also persists externally from which the mandible develops in membrane. The maxillary process of the mandibular arch and its derivatives have been described along with the development of the face.	Muscles of mastication such as temporalis, medial and lateral pterygoids and masseter, mylohyoids, anterior belley of digastric and tensor palati muscles.	*Ventral part of 1st Visceral Pouch.* Is obliterated with the appearance of tuberculum impar and formation of a part of the tongue. *Dorsal part of 1st visceral pouch.* Becomes enlarged and joins with the dorsal part of the second pouch to form a common recess, the tubo-tympanic recess from which the pharyngo-tympanic tube, the middle ear and its diverticulum, the tympanic antrum with the mastoid air-cells, and the inner lining of the tympanic membrane are developed.	Maxillary and external carotid	Mandibular division of trigeminal

Visceral Arches and Clefts	Ectodermal Derivatives	Mesodermal Derivatives		Entodermal Derivatives	Blood Vessels	Nerves
		Skeletal Elements	Muscle Mass			
Second arch and cleft	The ectodermal lining of the second, third and the fourth visceral clefts and *arches is overhung* by the down-growth from the caudal part of the second arch and the cervical sinus is formed *in* this situation (see text on external p h a r y n g e a l grooves) which usually *obliterates after some* time. The ectoderm of the second and third arches together with the epipericardial ridge form the whole of the skin of the side of the neck.	*Hyoid bar* or *Reichert's cartilage.* It can be divided into the following segments dorsoventrally: (1) Dorsal segment forms the stapes. (2) Tympano-hyal segment forms the root of the styloid process. (3) *Stylohyal segment* forms the rest of the styloid process. (4) Epihyal segment forms the stylohyoid ligament (5) Ceratohyal segment forms the lesser cornu of hyoid bone (6) Basihyal segment. It forms the upper part of the body of the hyoid bone	All muscles supplied by seventh nerve. Stylohyoideus, posterior belly of digastric, s t a p e d i u s, muscles of facial expression i.e. muscles of scalp, eye-lid, nose, mouth, auricle including the buccinator and the platysma *and also muscles of* upper and lower lips.	*Dorsal part of the second pharyngeal pouch* forms the tubo-tympanic r e c e s s along with the adjoining part of the first pharyngeal pouch (see above). Its *ventral part* forms the palatine tonsil.	Stapedial and external carotid.	Facial or seventh nerve.
Third arch and cleft (See above)		Its ventral part. (thyrohyal segment) forms the greater cornu *of the hyoid* bone and lower part of body of hyoid bone (basihyal).	Stylopharyngeus muscle and the carotid body.	*Ventral part.* Thymus gland *Dorsal part.* Inferior parathyroid glands and the piriform fossa.	Primitive third aortic arch	Glosso-pharyngeal or ninth cranial nerve.

Visceral Arches and Clefts	Ectodermal Derivatives	Mesodermal Derivatives		Entodermal Derivatives	Blood Vessels	Nerves
Fourth arch and cleft	The ectodermal lining of the fourth arch and cleft does not form any skin of the neck because it is buried by the dorsicaudal border of the cervical sinus.	The ventral part of the fourth pharyngeal arch cartilarge forms the epiglottis. The thyroid cartilage also develops from 4th arch cartilage. Thyrohyoid ligament, cuneiform cartilage of the larynx are also said to be formed from 4th arch cartilage.	Pharyngeal and laryngeal muscles such as cricothyroideus, transverse arytenoideus and inferior constrictor pharyngis.	Ventral part of fourth pouch forms the thyroid rudiment. Its dorsal part forms superior parathyroid bodies.	Arch of aorta on left side, proximal part of right subclavian artery i.e., first and second part of right subclavian	Superior laryngeal nerve (fibres of accessory through vagus and superior laryngeal).
Fifth arch and cleft	Epithelium of the lower neck is formed by the ectoderm of the fifth pharyngeal arch and cleft	Ventral part of fifth arch cartilage forms part of the thyroid cartilage, corniculate and cricoid cartilages of the larynx.	Remaining pharyngeal and laryngeal muscles.	Entoderm of the fifth pharyngeal pouch forms the ultimobranchial bodies. It also forms the epithelial lining of the oral part of mouth cavity and tongue, larynx and pharynx. Its dorsal wall forms the Seessel's pouch.	Blood Vessels disappear.	Recurrent laryngeal nerve (fibres of accessory through vagus and recurrent laryngeal).
Sixth arch		Tracheal cartilages (?) cricoid cartilage (?)	Sternomastoid and trapezius muscles		Blood vessels mostly disappear.	Accessory or the eleventh cranial nerve.

the bilateral rudiment of the inferior parathyroid and the thymus glands. The bilateral rudiments of the thymus later on fuse together to form the thymus gland proper.

Fourth pharyngeal pouch. The dorsal portion of the fourth pharyngeal pouch differentiates into a solid entodermal growth which later on becomes detached from the pharyngeal wall and forms the superior parathyroid of the adult. The ventral portion of this pouch develops into the latral lobe of the thyroid gland.

Fifth pharyngeal pouch. This forms a small entodermal diverticulum from the pharynx and lies behind the fourth pouch. With further development it usually disappears but sometimes it persists as *ultimobranchial body* or *cyst* which is closely related to the inferior pole of the thyroid.

In addition to the pharyngeal pouches on the lateral walls, the primitive pharynx also presents some features of interest on its ventral wall and the roof.

The *ventral wall* or the *floor of the primitive pharynx* presents the following features :

The first pharyngeal arch or the mandibular arch unites with the fellow of its opposite side at the median plane and the union of the two is marked by an inverted Λ-shaped groove and enclosing between its two limbs is a small nodular growth known as the *tuberculum impar*. Just caudal to the tuberculum impar opposite the median plane the ventral wall sends out a diverticulum, the *thyroid bud*, from which the isthmus and part of the lateral lobe of the thyroid gland develop during later periods. The second pharyngeal arches are continuous with each other opposite the median plane. The third and the fourth pharyngeal arches do not meet with their fellows in the median plane but their ventral ends meet at a median eminence known as the *hypobranchial eminence*. The fifth arch is almost indiscernible. Immediately caudal to the hypobranchial eminence is a sagittal slit which forms the *primitive lung diverticulum*. Immediately caudal to the lung diverticulum the more constricted portion of the fore-gut marks the commencement of the primitive œsophagus.

The *dorsal wall* or the *roof* of the primitive pharynx extends as far as the Rathke's pouch, an ectodermal diverticulum from the primitive mouth and is limited in front by the dorsal attachment of the bucco-pharyngeal membrane. It forms a diverticulum, *Seessel's pouch*, which gives rise to the *pharyngeal bursa*, a depression around which the pharyngeal tonsil which lies in the nasal part of the pharynx.

Development of the thyroid gland. The thyroid gland develops from the median thyroid diverticulum, derived from the ventral aspect of the primitive pharynx just caudal to the tuberculum impar, as well as from the ventral ends of the fourth pharyngeal pouches. For details, see thyroid gland.

The foregut below the primitive pharynx. The foregut below the primitive pharynx develops into œsophagus, stomach, duodenum (up to the attachment of the common bile duct), the liver and its excretory apparatus, and the pancreas.

The œsophagus. The constricted portion of the foregut that lies cranial and dorsal to the septum transversum and in between the two limbs of the ∩-shaped cœlomic cavity, gives rise to the formation of the œsophagus. At this stage it is connected to the posterior body wall opposite the median plane by a membranous mesodermal fold known as the meso-œsophagus which is continuous caudally with the dorsal mesogastrium, and ventrally, it still remains connected with the septum transversum. At the caudal part of the dorsal region of the septum transversum the œsophagus is continuous with the more dilated part of the foregut, the stomach.

The stomach. The dilated portion of the foregut dorso-caudal to the septum transversum results in the formation of the stomach which is suspended from the dorsal wall by the *dorsal mesogastrium*. Ventrally, during the earlier part of development, both the œsophagus and the stomach are directly connected to the septum transversum, and below this attachment the gut tube opens into the yolk sac. Subsequently the stomach and the œsophagus draw out the septum transversum in the form of a thinned out lamina which connects the septum transversum ventrally with the stomach and the œsophagus. This thinned out fold is called the *ventral*

mesogastrium. Thus, caudally, the ventral mesogastrium extends up to the caudal limit of the septum transversum beyond which the gut tube is in direct communication with the yolk sac which forms the mid-gut.

At first the stomach which simply forms a dilated tube, is held vertically opposite the median plane by the dorsal and the ventral mesogastria; at this stage its borders are ventral and dorsal, and its surfaces are right and the left, and there is no differentiation of its different parts as well as no differentiation of the duodenum from it. Subsequently its dorsal border grows more than its ventral border and as a result, its dorsal border becomes elongated and convex and at the same time the cranial part of this border forms a dome-shaped bulging —the fundus of the stomach.

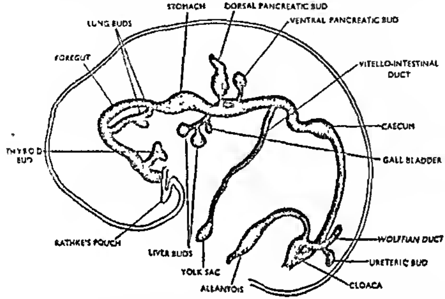


Fig. 160 The developing digestive tube with the structures that develop from it (Diagrammatic

Concurrently with these changes two recesses, *pneumo-enteric* and the *bursa omenta* appear within the dorsal mesogastrium. The pneumo-enteric recess ascen cranially on the right side and intervenes between the right edge of the œsophag and the right lung-bud. The second recess, known as the bursa omentalis, exten gradually on the left side and together with it carries the stomach to the left of t median plane and as a result, the stomach rotates to the left which brings about change in its disposition in which its right surface comes to lie dorsally ventral the omental bursa, whereas its left surface comes to lie ventrally. Meanwhi further growth results in the differentiation of the pyloric portion and the duodenum

As a result of rotation of the stomach to the left side the duodenum also suffe a change in its disposition; and because of its having a short, rudimentary dors mesentery it is permitted to have a very short range of movement and consequent it comes to lie on the dorsal wall.

The Liver. At the caudal end of the ventral mesogastrium the fore-gut tub sends out a hollow diverticulum within the septum transversum which subsequen develops into the *liver.* The position of the liver diverticulum marks the terminatio of the fore-gut beyond which the mid-gut commences. For details see discriptio of the liver.

The Pancreas. The pancreas develops from a *dorsal* and a *ventral bud.* Th dorsal bud comes out from the fore-gut dorso-cranial to the hepatic bud whereas th ventral bud comes out from the right side of the hepatic bud proper. For detai see the description of the pancreas.

THE MID-GUT AND THE HIND-GUT

The mid-gut. The mid-gut commences as a direct continuation of the fore-gut from below the level of the opening of the common bile duct into the second part of the duodenum and ends in the hind-gut at the junction of the middle and the left-third of the transverse colon. Thus it is found that part of the duodenum (from below the opening of the common bile duct), jejunum, ileum, cæcum, vermiform appendix, ascending colon and greater part of the transverse colon are derived from the mid-gut loop.

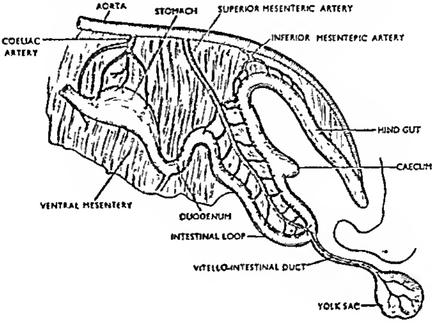


Fig. 161. Rotation of the gut—first stage.

The mid-gut loop during the earlier part of development is formed mostly by the yolk-sac. Later on, with growth of the embryo and the mid-gut loop, the latter forms a ∩-shaped loop which together with its mesentery still lies in the sagittal plane having its convexity ventralward. At this stage the yolk-sac is much reduced in size and it remains connected with the apex of the ∩-shaped mid-gut loop by a narrow passage of communication known as the *vitello-intestinal duct*. The vitelline artery which later on becomes the superior mesenteric artery, in its course from the dorsal aorta passes in between the two limbs of the ∩-shaped loop, sending out branches to both the segments and thus divides the segments of the ∩-shaped loop into *cranial* or *pre-arterial segment* and *caudal* or *post-arterial* segment. The pre-arterial segment is destined to form the small intestine whereas the post-arterial segment is destined to form the large intestine. Subsequently, during the fifth week of fœtal life when the available space within the cœlomic cavity is almost entirely occupied by the rapidly growing liver and the mesonephros the mid-gut loop, particularly its pre-arterial segment, also grows rapidly and due to want of space within the cœlomic cavity the growing mid-gut loop is herniated into the umbilical cord within the umbilical sac forming a *temporary physiolo-*

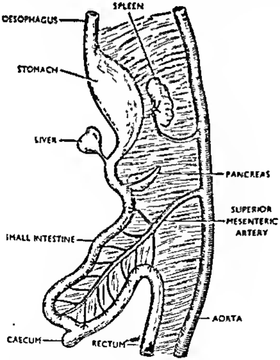


Fig. 162. Rotation of gut—first stage.

gical hernia. With further growth the gut loops rotate anti-clock-wisely with the following sequence of events.

Rotation of the gut. The rotation of the gut commences during the fifth week of fœtal life and continues *till the eleventh week and finally they are fixed in position* and the process of fixation commences from the eleventh week and continues until shortly after birth of the fœtus. Thus the process of rotation of the gut can be split into two stages (*i*) stage of rotation and (*ii*) stage of fixation. For convenience the stage of rotation is further split into first and second stages.

First stage of rotation This stage begins during the fifth week of fœtal life and continues till tenth week when the herniated loop still lies within the umbilical cord.

Just before rotation the pre-arterial segment of the ∩-shaped loop grows out of proportion with the post-arterial segment and as a result, the pre-arterial segment *becomes coiled whereas the post-arterial segment which shows very much less growth* activity assumes a straighter course.

The rapidly growing liver causes undue pressure on the base of the pre-arterial segment of the herniated loop and as a result, it rotates anti-clockwisely through 90° having the superior mesenteric artery as the axis; thus the pre-arterial segment is pushed down and to the right and its counter limb, the post-arterial segment, rotates upwards and to the left.

Shortly afterwards at about the sixth week, a localised thickening appears on the herniated part of post-arterial segment which forms the rudiment of the cæcum. Concurrently with the appearance of the cæcal rudiment the vitello-intestinal duct together with the *segment of the vitelline artery* attached to it becomes detached from their connection with the free border of the intestinal loop and the latter becomes free. The remaining portion of the vitelline artery which lies in between the two loops and extends from the dorsal aorta to the mesenteric border of the intestine forms the superior mesenteric artery.

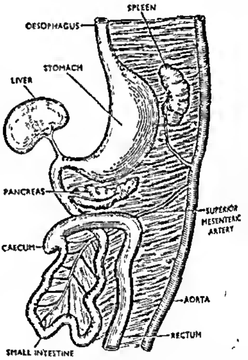


Fig. 163. Rotation of gut—second stage

Second stage of rotation. The second stage of rotation starts with the return of the herniated loop within the abdomen between the tenth and the eleventh week. During this time with reduction in size of the liver the intra-abdominal pressure is reduced (Frazer) and the available space within the abdominal cavity is increased and as a result, the herniated gut loop begins to return back into the abdominal cavity. The herniated loop is too bulky to be returned *en masse* and therefore a more gradual, *orderly return* takes place, beginning with the proximal part of the pre-arterial segment. The cæcal bulging which appears early during the sixth week in the post-arterial segment of the herniated loop forms the last structure to be reduced within the abdominal cavity. Although the superior mesenteric artery forms the main guiding axis in the rotation and return of the herniated loop the process of withdrawal is also aided and guided by the pull of the dorsal mesentery and some of the retention bands.

The proximal part of the pre-arterial segment of the herniated loop returns into the abdominal cavity on the right side of the superior mesenteric artery

but the space here is very much limited and therefore the gut loop is pushed to the left side *behind the stretched superior mesenteric artery.* In course of its way to the left the returning loop pushes the dorsal mesentery of the hind-gut from its median position to the left flank and consequently the descending colon comes to occupy the left flank and the colic angle is displaced upwards to form the future splenic flexure and the cæcum rotates upwards and to the right carrying the right half of the colon transversely *across the origin of the superior mesenteric artery from the dorsal aorta.* Ultimately the cæcum is also reduced within the abdominal cavity and it occupies its position immediately below the liver just after its withdrawal.

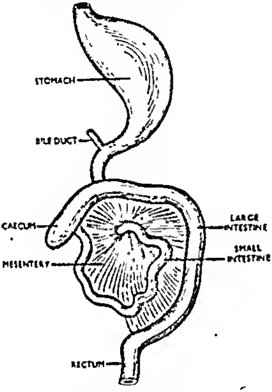


Fig. 164. Rotation of gut—second stage.

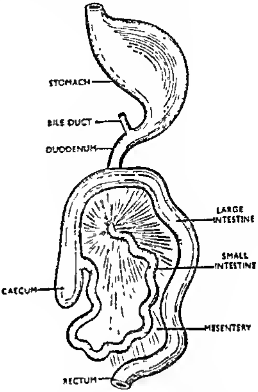


Fig. 165. Rotation of gut—second stage.

Stage of fixation. During this stage with further growth of the large intestine and diminution in size of the liver the cæcum descends to occupy its usual position in the right iliac fossa. The ascending colon is at first provided with its mesentery but later on it is pushed aside (right side) and is pressed against the posterior abdominal wall by the growing small intestine. It, being pressed against the posterior abdominal wall, loses its mesentery and comes to lie retroperitonially. The mesentery of the transverse colon usually persists which forms the transverse mesocolon. The mesentery of the pelvic colon also persists to form the pelvic mesocolon. The process of fixation begins at about the eleventh week and continues till shortly after the birth of the fœtus.

Anomalies found in association with the development of the mid-gut loop.

(1) MECKEL'S DIVERTICULUM. Sometimes (in about 2% of cases) the portion of the vitello-intestinal duct remains patent and connected with the mid-gut loop giving rise to the formation a diverticulum from the intestinal loop known as the Meckel's diverticulum. The diverticulum is usually found to make its appearance over the ileum within 2–4 feet from the ileo-cæcal orifice. Occasionally the diverticulum is provided with a short mesentery into which the vestige of the artery of the yolk-sac may persist and at the same time the attached border of the mesentery may be deficient in the intermediate position. Thus a gap may persist within the mesentery of the diverticulum through which some portion of the gut loop may be herniated and strangulated.

(2) Sometimes the yolk-sac portion of the vitelline artery persists as a fibrous cord which connects the umbilicus with the intestine; strangulation of some portion of the gut loop may occur around this fibrous band.

(3) Sometimes the vitello-intestinal duct remains patent throughout and remains extended into the umbilical cord. Under such condition division of the umbilical cord after birth results in the formation of a fistulous tract at the naval through which intestinal content comes out; occasionally some portion of the vitello-intestinal duct may remain attached with the wall of the umbilical cord and after birth may give rise to a condition known as "weeping naval" in which, the cord wound instead of healing, is turned into a discharging ulcer.

(4) *Umbilical hernia.* The normal umbilical hernia of early fœtal life, due to failure of mechanism of the withdrawal back of the gut into the abdominal cavity, may persist even after birth in some cases giving rise to the condition of umbilical hernia

The Hind-gut. The hind-gut begins as a continuation of the transverse colon of the mid-gut within a short distance from the left colic flexure and ends in the cloaca. Parts derived from the hind-gut are a small portion of the transverse colon, the descending colon, the pelvic colon, the rectum, the upper portion of the anal canal, greater part of the urinary bladder, female urethra and the prostatic part of the male urethra up to the opening of the ejaculatory ducts.

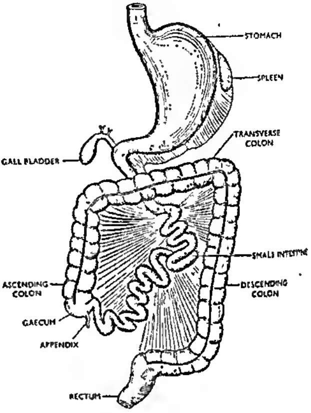


Fig. 166. Final position of the gut after rotation.

The cloaca. The caudal end of the primitive gut tube ends in a pouch-like blind extremity known as the cloaca. It forms a common entodermal chamber into which the hind-gut, the allantois and the two mesonephric ducts open. At this stage, on either side of the cloaca, is a mass of mesoderm which gradually spread across the median plane to form a median septum. This mesodermal septum intervenes between the allantois ventrally and the hind-gut dorsally and is in contact with the cloaca caudally. Into this median mesodermal septum the caudal ends of the two mesonephric ducts are embedded and are in relation with the cloaca dorsolaterally. This median mesodermal septum which is called the *cloacal septum* then extends cranio-caudally into the cloaca dividing it into ventral and dorsal portions. The dorsal portion forms the rectum whereas the ventral portion constitutes the uro-genital sinus. Concurrently with the division of the cloaca the cœlomic cavity extends caudally between the median mesodermal septum or the cloacal septum and the rectum. Thus the mesonephric ducts which remain embedded in the cloacal septum come to lie in relation with the uro-genital sinus portion of the cloaca into which they open. The cranial portion of the urogenital sinus is formed by the allantois which is later converted into the urachus; the portion above the opening of the mesonephric ducts and between them and the allantois gives rise to the

urinary bladder while the remaining portion i.e., the portion containing the openings of the mesonephric ducts and the part below them gives rise to the formation of the proximal part of the prostatic urethra in the male and the whole of the urethra in the female.

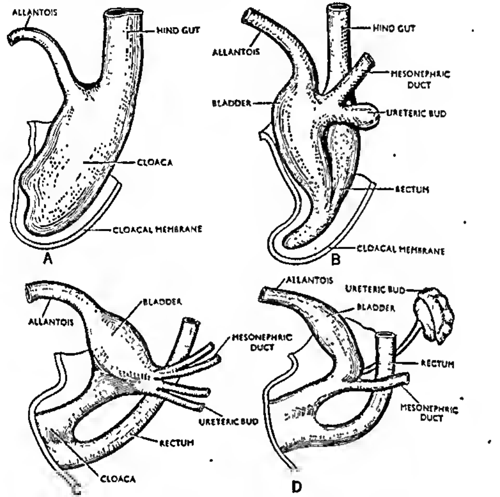


Fig. 167. The cloaca and its sub-divisions and the structures that open into it.

RESPIRATORY SYSTEM

The main respiratory organ, that is, the laryngo-tracheo-bronchial tree together with the lungs is an entodermal derivative of the fore-gut and arises as a diverticulum from the ventral wall of the primitive pharynx. During the fourth week of intra-uterine life, when the embryo is about 3 mm. in length, a groove appears on the ventral wall of the primitive pharynx caudal to the hypobranchial eminence known as the *laryngo-tracheal groove*. This groove extends cranio-caudally, and at first, it lies caudal to the ventral ends of the fourth phryngeal arches and between the ventral ends of the fifth and sixth pharyngeal arches. The groove gradually deepens and extends caudally. The margins of the groove gradually fuse together from the caudal end and ultimately the groove is converted into a tube the cranial end of which remains open and forms the opening of communication between the larynx and the pharynx. The tube thus formed is known as the *laryngo-tracheal tube* which has a blind caudal end and an open cranial end connected to the primitive pharynx. The laryngo-tracheal tube thus overlies the ventral aspect of the pharyngo-œsophageal tube and appears as its ventral diverticulum. The caudal end of the laryngo-tracheal tube then becomes bulbous to form the primodium of the *lung bud*. The lung bud soon bifurcates into two unequal ***pulmonary diverticula***, "*primary bronchi*" *right* and *left*

swelling on each side extends cranio-ventrally to join with the hypobranchial eminence at its sides and forms the basis of the future ary-epiglottic folds, one on each side, which bound the inlet of the larynx in the adult. Then the inlet of the larynx in the adult is the secondary laryngeal opening brought about by the development of the super-structure on either side of the opening of the laryngo-tracheal tube which is the primary laryngeal opening.

Thyroid cartilage. The thyroid cartilage develops as two mesodermal plates derived from the ventral ends of the fourth and the fifth pharyngeal arches.

Cricoid cartilage. The skeletal element of the sixth pharyngeal arch divides into dorsal and ventral portions. The dorsal portion gives rise to the formation of the arytenoid and corniculate cartilages whereas its ventral portion forms the cricoid cartilage and the cartilaginous tracheal rings.

The Cavum laryngis. In a 6 mm. embryo the cavity of the larynx is represented by the extreme cephalic end of the entodermal laryngo-tracheal tube together with the slit like opening which communicates the laryngo-tracheal tube with the primitive pharynx. At this stage the slit-like opening of communication is bounded on either side by the mesodermal condensation at the ventral ends of the fifth and sixth pharyngeal arches and lies immediately caudal to the hypobranchial eminence. With further development the cephalic end of each lateral swelling (the super-structures) extends upwards to join with the hypobranchial eminence and forms the ary-epiglottic folds. Later on excavation appears on the medial side of the ary-epiglottic folds and forms the *sinus of the larynx* and its two margins, cranial and caudal, form respectively the *vestibular and the vocal folds.* The opening bounded by the ary-epiglottic folds forms the inlet of the larynx (secondary laryngeal orifice) and the bilateral swelling known as the arytenoid swelling gives rise to the formation of the arytenoid, corniculate and cricoid cartilages.

DEVELOPMENTAL ANOMALIES: Anomalies found in the development of the lungs are of various degrees of arrested growth, and other types of defects without any arrest of growth. According to Schneider's classification, which is based on the degree of arrest of growth, anomalies of the lungs are of three types, type I, type II and type III.

Type I (Agenesis). This is a defect in which there is complete absence of the bronchus and the lung.

Type II (Aplasia). In this type of defect there is a rudimentary bronchus but there is no associated lung tissue.

Type III (Hypoplasia). In this type of anomaly there is a bronchus with variable amount of lung parenchyma which is usually subnormal in development.

OTHER TYPES OF ANOMALIES: (*a*) *Lobus venæ azygos or the lobe of the azygos vein.* *This is a condition* in which the upper lobe of the right lung is split into two by a pleural septum which runs vertically from either the lateral or medial side of the apex towards the lung root; at the lower curved border of the septum there lies the accentuated arch of the azygos vein which gains its termination in the superior vena cava at a higher level opposite its formation by the two innominate veins. The azygos venous lobe may be present on the left side also.

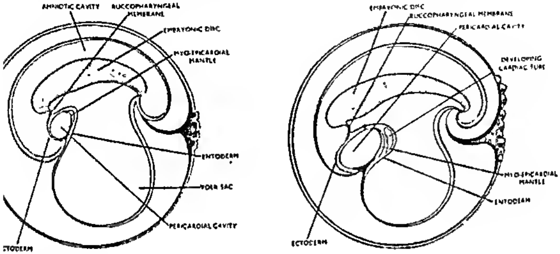
(*b*) *Defects in the bronchial tree:* Congenital dilatation of the terminal bronchioles may result in the formation of *congenital bronchiectasis. Congenital cyst of the lung* is another condition, often associated with accessory pulmonary arteries, where there is enormous dilatation of the bronchioles due to compression of a segment of a bronchus by the accessory pulmonary artery above the dilated bronchioles.

(*c*) *Vascular anomalies.* Accessory pulmonary artery. The accessory pulmonary artery occasionally arises from the abdominal aorta just above the diaphragm and follows the pulmonary ligament to enter into the lower lobe. It may, however, arise from the abdominal aorta below the diaphragm or occasionally it may even arise from the inferior phrenic artery.

CARDIO-VASCULAR SYSTEM

DEVELOPMENT OF THE HEART

EXTERNAL FORM. The pericardial cavity is formed by that portion of the ıtra-embryonic cœlom which passes transversely across the middle line in front of ıe future buccopharyngeal membrane (prochordal plate). The pericardial cavity plits the mesoderm in this region, which intervenes between the entoderm in front nd ectoderm behind, into two layers, *intra-embryonic somatopleuric mesoderm* and *intra-mbryonic splanchnopleuric mesoderm.* The former lines the pericardial cavity towards he ectoderm while the latter lines that towards the entoderm. The mesenchymal ells that intervene between the splanchnopleuric mesoderm and the entoderm



'orm a network of cells known as the *:ardiogenic plate.* The cells of the cardiogenic plate differentiate *in situ* to form endothelial cells which form two *endothelial tubes.* The splanchnopleuric mesoderm dorsal to the endothelial tubes gives origin to *myo-epicardial mantle* which, later on, is transformed into myocardium and the epicardium of the future heart. By the time the head fold has developed considerably it causes rotation of the pericardial cavity through 180° and as a result, the endothelial tubes lie ventral to the developing foregut, dorsal to the pericardial cavity, caudal to the buccopharyngeal membrane and craniodorsal to the septum transversum. Each of the endothelial tubes soon becomes connected at its caudal end with the dilated venous sinus formed by the union of the corresponding vitelline and the umbilical veins. This dilated venons sinus on each side is called the *primitive sinus venosus* which is soon oined by the *duct of Cuvier* or the common venous channel formed by the union of the anterior and posterior cardinal veins of the same side. Thus it is evident that the primitive sinus venosus of each side receives the corresponding vitelline, umbilical, and the anterior and posterior cardinal veins. The cranial end of each of the endothelial tubes extends beyond the pericardial cavity and is joined

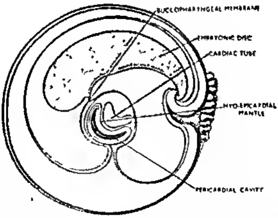


Fig. 170. Diagrammatic representations to show the relations of the developing heart and the pericardial cavity.

with the corresponding dorsal aorta, which develops *in situ* from the mesodermal cells on the sides of the notochord, by aortic arches.

With these changes the endothelial tubes undergo gradual fusion from cranial to the caudal end and the resulting single endothelial tube is the *primitive heart tube.* The myo-epicardial mantle now is transformed into myocardium and epicardium, and the single endothelial tube becomes the *endocardium.* The myo-epicardial mantle together with the endothelial heart tube, being invaginated into the peri cardial sac, is suspended from the dorsal pericardial wall by a double fold of serou pericardium called the *mesocardium.* This mesocardium only exists temporaril and at about sixteen-somite stage this disappears altogether leaving a gap which in later life, forms the *transverse sinus of the pericardium.*

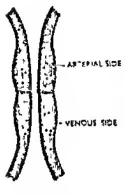


Fig. 171. Two endothelial tubes.

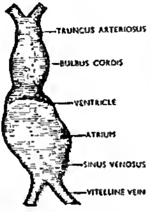


Fig. 172. The primitive heart.

At this stage the endothelia tube together with the myo-epi cardial mantle is called the *cardia tube* or the *primitive heart.* Th cardiac tube then elongates withi the pericardial cavity, and th tube, being fixed at its both ends becomes folded on itself. Now differential growth in the wall o the cardiac tube becomes manifes which results it to be sacculate with grooves or sulci on its exter nal aspect. These dilatations wit grooves subdivide the cardiac tub into different components exter nally, and from caudal to th cranial end, they are the *right an left sinus venosus, right and left primi tive atria, atrio-ventricular canal,* th *ventricles* and *the bulbus cordis.* At this stage the right and left sinus venosus and th right and left primitive atria are still embedded in the septum transversum.

The cardiac tube being fixed with the pericardium at its arterial and venou ends, rapid growth of the cardiac tube, which greatly exceeds that of the pericardia cavity, causes it to be bent on itself to form a U-shaped loop, the convexity of whic is directed ventrally and to the right. As this loop involves mainly the ventricle and the bulbus cordis it is called the *bulbo-ventricular loop.* The concavity of th bulbo-ventricular loop gradually deepens to form the *bulbo-ventricular sulcus.* Wit these changes in the bulbo-ventricular part of the cardiac tube its venous end als undergoes changes in which the right and the left atria become fused to form a transversely dilated *single atrium.* This single atrium thus formed becomes freed from the septum transversum and comes to lie within the pericardial cavity where it is placed dorsal to, and partly to the left of the bulbo-ventricular loop. Subsequently the right and the left sinus venosus are separated from the septum transversum and they come to lie dorsal to the single atriu of en the sinus venosus m.

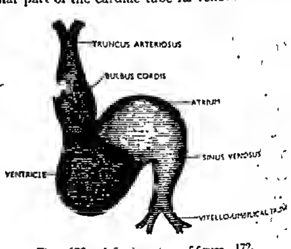


Fig. 173. A further stage of figure 172.

the two sides undergoes partial fusion as a result of which, the two different sino-atrial orifices become fused to form a single sino-atrial orifice which opens into the single atrial cavity. Then with further development re-arrangement of veins entering into the sinus occurs and a new venous channel, the *ductus venosus* is formed and most of the blood from the liver passes through this to the right sinus horn. With these changes the left sinus is much reduced in size and a deep sulcus appears between this and the left side of the common sinus venosus and most of the blood being passed through the ductus venosus to the right sinus horn the latter becomes enlarged and becomes separated from the dorsal aspect of the atrium. While these changes take place the single sino-atrial orifice which was transversely placed, becomes vertically disposed and the margins of the opening project into the atrium as *right* and *left venous valves*.

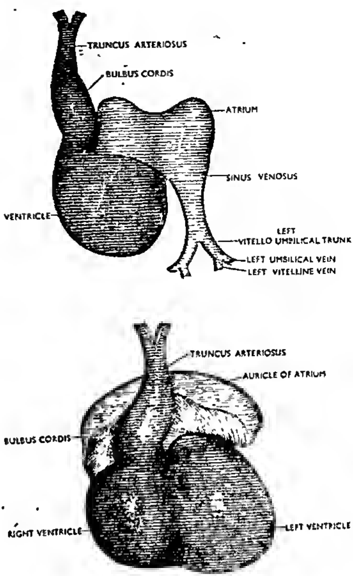


Fig. 174. The stages in the development of the external form of the developing heart.

Concurrently with the above changes the heart as a whole gradually becomes caudally displaced; as a result of this caudal migration, and with subsequent development of the neck, the anterior cardinal veins, which were vertical in direction, become oblique in direction. The obliquity of the anterior cardinal veins produces corresponding oblique ridges in the pericardio-pleural opening and are known as *pericardio-pleural folds*. These folds become sufficiently enlarged and ultimately separate the pericardial cavity completely from the pleural cavity.

Subsequently all the new components of the heart become rapidly enlarged and they are further re-arranged in their position. The atrium enlarges transversely and from either side they embrace the bulbus cordis and ultimately the portions that overlap on the sides of the bulbus cordis form the auricular appendages. Then the bulbo-ventricular sulcus becomes much reduced in depth and some portion of the bulbus cordis becomes absorbed into the ventricle which has now moved more on the left side. The atrio-ventricular groove becomes much accentuated and a narrow waist, the *atrio-ventricular canal* is formed. With these changes the external form of the heart assumes almost a normal adult form.

Interior of the Heart. As already described the single cardiac tube has been so oriented as to form the different chambers of the heart but major changes

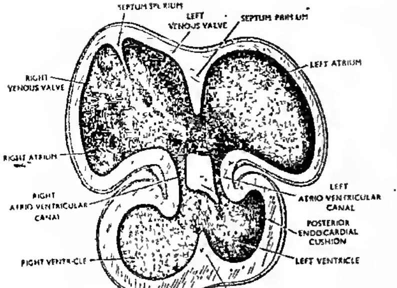


Fig. 175. The stages in the development of the internal form of the developing heart.

are still to be involved in forming partitions within the heart so as to demarcate one chamber from the other. Although processes of separation run concurrently with the changes of its external form it would be convenient to discuss them separately and individually.

Atrium. At 7.5 mm. stage the embryonic heart is dumble-shaped with a narrow waist and with expansions both above and below. The upper expanded portion is formed by the common atrium and the lower two by the ventricles. The accompanying diagram is the approximate picture of the interior of the heart at this stage. The common atrial chamber communicates with the ventricle by a narrow canal, the *atrio-ventricular canal* (A.V canal) through the narrow waist. The A.V. canal is at first circular in form but soon it becomes transversely widened. The right side of the common atrium (future right atrium) contains the opening of the sinus venosus which is bounded by the right and the left venous valves. Superiorly the right and the left venous valves fuse together to form a well marked projection on the roof of the right side of the atrium known as the *septum spurium*. Inferiorly also they fuse together but form an ill-defined elevation. A sickle-shaped sagittal fold, the *septum primum*, soon extends from the roof of the atrium opposite the middle line and lies on the left side of the septum spurium. The septum primum corresponds to a mid-line furrow externally caused by the inward thrust of the distal portion of the bulbus cordis. Concurrently with the appearance of the septum primum the ventral and the dorsal walls of the A.V. canal become elevated opposite the middle line and these elevations are called the *atrio-ventricular endocardial cushions dorsal* and *ventral*. Then the septum primum extends gradually downwards and the

anterior and posterior atrio-ventricular endocardial cushions gradually fuse together opposite the middle line and divide the A.V. canal into right and left atrio-ventricular openings. The free or the lower edge of the septum primum is still to reach the A.V. endocardial cushion and the opening between the two is called the *foramen primum* or *primary foramen ovale* which soon becomes obliterated by the fusion of the lower edge of the septum primum with the fused upper surface of the A.V. endocardial cushion. Thus the common atrium is divided into right and left atria. Concurrently with this process of fusion the cephalic end of the septum primum undergoes degenerative changes and an opening appears between it and the roof of the atrium and this opening, the *foramen secundum*, communicates the two atria together.

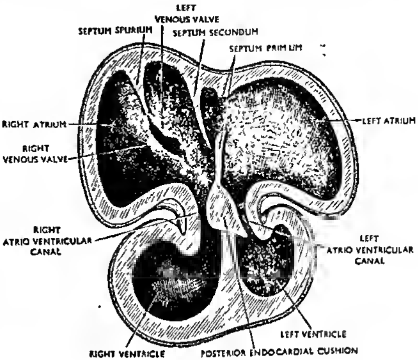


Fig. 176. Formation of foramen ovale, inter-atrial and inter-ventricular septa

This foramen secundum is the *secondary foramen ovale*. The space between the septum primum and the septum spurium is called the *interseplo-valvular space*. From the roof of the right atrium opposite this space, the *septum secundum* soon appears and gradually extends downwards to reach the upper margin of the septum primum which has become deficient to form the foramen secundum.

The opening still left by the lower concave margin of the septum secundum and the upper margin of the septum primum is the *foramen ovale*. Then the crescentic lower margin of the septum secundum overlaps the upper margin of the septum primum and the foramen ovale becomes a valvular opening. Until the birth of the fœtus most of the blood from the inferior vena cava passes into the left atrium through this valvular opening because of the inequalities of pressure of blood between the two atria, the right atrium presumably has a greater pressure. After birth, with the establishment of pulmonary circulation, the pressure of blood between the two atria becomes equal and consequently flow of blood from right to the left atrium ceases altogether; the opening is closed by fusion of the opposed surfaces of the overlapping margins (about 75 per cent of cases). In about 25 per cent of cases, the opposed overlapping surfaces of the septum primum and septum secundum fail to fuse together and consequently, anatomically a patent foramen ovale persists, though closed physiologically, because of the absence of any flow through this foramen. Rarely, in certain percentage of cases, the margin of the septum secundum fails to meet the margin of the septum primum and consequently, this type of foramen ovale becomes patent both anatomically and physiologically. In normal cases where the foramen ovale is completely closed its position is marked by a depression, the *fossa ovalis* on the septal wall under an arched rim-like elevation, the *annulus ovalis*.

Right atrium. If we trace back to the embryological components of the adult right atrium it is seen that the adult right atrium is formed by three embryo-

logical components, viz., the *right half of primitive atrium*, the *right half of sinus venosus* and the *right half of the A.V. canal.* The auricles with the musculo-pectinati develop from the primitive atrium and the remaining smooth portion is formed by the sinus venosus while the right half of the A.V. canal forms the right atrio-ventricular orifice. The crista terminalis marks the line of fusion between the primitive atrium and the sinus venosus and corresponds to the sulcus terminalis externally.

Parts derived from the right and left venous valves of the sinus venosus. During the process of growth and development the sinus venosus is gradually absorbed into the primitive atrium. The left venous valve disappears while the right venous valve is displaced centrally and to the right by the developing sinus venosus and it gives out three subendocardial muscular processes known as the *limbic bands.* The *superior limbic band* passes across the posterior wall of the sinus venosus between the orifices of the superior and the inferior venæ cavæ and form the basis of the *intervenous tubercle of Lower.* The *inferior limbic band* is situated between the orifices of the inferior vena cava and the coronary sinus (rudiment of the left horn of sinus venosus) and forms the basis of sinus septum. That portion of the right venous valve which extends above the superior limbic band fuses with septum spurium to form the *crista terminalis.* The portion of the right venous valve between the superior and inferior limbic bands persists as the *valve of the inferior vena cava* and the *valve of the coronary sinus.*

Left atrium. The left atrium develops from the *left half of the primitive atrium,* the *dilated terminal portions of the pulmonary veins* and the *left half of the A.V. canal.* The left auricle is formed by the left primitive atrium.

Ventricles and the bulbus cordis. The common ventricular cavity is divided into right and left ventricles by the growth of the interventricular septum. Shortly after the appearance of the septum primum of the atrium, an antero-posterior muscular ridge appears in the floor of the bulbo-ventricular cavity. With further growth posterior part of this interventricular septum approaches the right extremity of the postero-inferior aspect of the A.V. cushion and then subsequently fuses with the same. The anterior part of the interventricular septum extends from the anterior wall and roof of the common bulbo-ventricular cavity and finally fuses with the antero-superior part of the A.V. cushion. Thus the interventricular septum is seen to be fused with the anterior and the posterior parts of the A.V. cushion but in the intermediate position it does not reach the A.V. cushion and ends in a free concave margin. The foramen formed by the free concave margin of the interventricular septum and the A.V. cushion is called the *interventricular foramen* which communicates the two ventricles for a short time. Later on, the interventricular foramen is closed by the proliferation of the lower part of the right and left bulbar ridges and fused A.V. cushion.

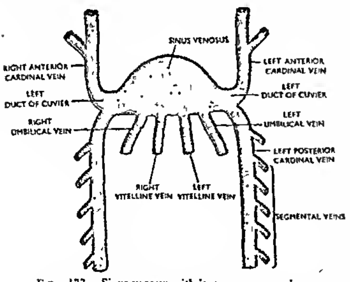


Fig 177. Sinus venosus with its venous connections.

Shortly before the formation of the interventricular septum a spiral sub-endo cardial thickening appear within the bulbus cordis and is known as the *bulbar ridges*

In the distal part of the bulbus cordis the bulbar ridges are placed laterally; in the proximal portion they form right and left bulbar ridges and are placed above the right A.V. canal and the interventricular septum respectively; in the intermediate position they are so arranged as to be placed on the anterior and posterior walls. With further development these ridges fuse together and a *spiral aortico-pulmonary* septum is formed which divides the bulbus cordis into the aorta and the pulmonary trunk which communicate with the left ventricle and the right ventricle respectively.

Pars membranacea septi. The membranous part of the interventricular septum is formed by the fibrous tissue and remains so throughout life. Though it is called interventricular septum it is partly interventricular and partly atrioventricular. Its lower part intervenes between the right and the left ventricles while its upper part intervenes between the left ventricle and the right atrium. The interventricular part of the septum is formed by the extension and fusion of the right and the left bulbar ridges while the atrio-ventricular part is developed by proliferation of the cells of the fused A.V. cushion.

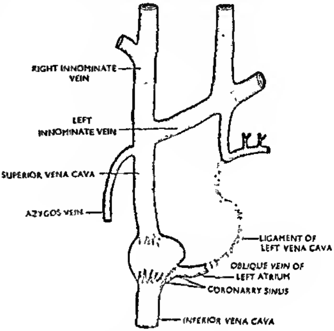


Fig. 178. The fate of sinus venosus.

Fate of sinus venosus. The superior and inferior venæ cavæ open into the right horn of the sinus venosus in the developing heart. As the right atrium gradually enlarges it entirely absorbs the right horn into its wall and therefore the venæ cavæ (superior and inferior) are connected into the right atrium and gain separate openings into it. The left horn of the sinus venosus may persist and form a part of the oblique vein of the left atrium. The body of the sinus venosus persists as the coronary sinus which opens into the right atrium between the openings of the inferior vena cava and the right atrio-ventricular orifice. The coronary veins drain into the coronary sinus.

VASCULAR SYSTEM

The vascular system of the embryo consists of networks of endothelial tubes which appear almost simultaneously both within the embryo and outside, in the yolk-sac, body stalk and in the chorion. By the intricate process of fusion, amalgamation and retrogression definitive blood vessels are formed within the embryo, in the yolk-sac and the body stalk. By the process of extension the extra-embryonic vessels establish communication with the intra-embryonic vessels and thus, together with the developing heart within the embryo a simple circulatory system is established between the embryo and the developing placenta. The developing blood vessels consist of two systems of blood vessels namely the arterial and the venous systems.

THE ARTERIAL SYSTEM

The main arteries formed within the early embryo are the *ventral aorta* and the *aortic arches* and the *two dorsal aortæ with their branches.* The primitive heart within the embryo is formed by the fusion of two endothelial tubes (see development of

heart) and is connected with the ventral aorta at its cephalic end through the medium of a short arterial trunk known as the *truncus arteriosus*, and with the sinus venosus, a common venous chamber, at its caudal end. At this stage the two umbilical arteries, one on each side, which form the terminal branches from the corresponding dorsal aorta, grow out in the umbilical cord and establish connection with the venous capillaries of the umbilical veins in the placenta. Thus a simple circulatory system is established between the embryo and the placenta.

Ventral Aorta and the Aortic Arches. It has already been learnt that the primitive cardiac tube consists of a cranial end known as the *bulbus cordis* and a

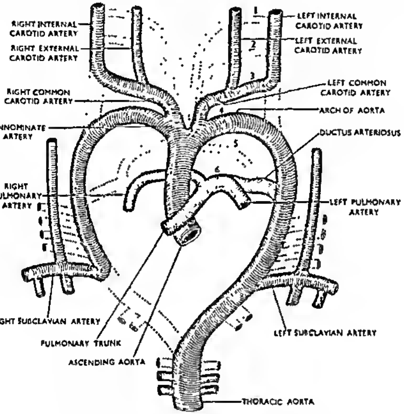


Fig. 179. The aortic arches and their derivatives.

caudal end known as the *sinus venosus*. The bulbus cordis at its cranial end forms a short common arterial trunk, the *truncus arteriosus*, which leads to a dilated sac known as the *aortic sac* or the *primitive ventral aorta*. The aortic sac breaks up into branches which enter into the pharyngeal arches from both sides and form a series of arches known as the *aortic arches*.

The aortic arches are six in number on each side and form a right and a left set of branches. Each aortic arch passes upwards and backwards in the corresponding visceral arch and establish connection with the corresponding dorsal aorta. The aortic arches appear between fourth and sixth weeks of intra-uterine life and undergo extensive changes within a short time. The first aortic arch appears first during the beginning of fourth week and then in a rapid succession the remaining arches develop cranio-caudally and by the sixth week, the sixth or the last arch develops. By the time the sixth aortic arch develops, the first and the second aortic arches have already atrophied and disappeared. The fifth arches connect the fourth arches with the sixth and persist only for a short time and soon disappear.

Fate and derivatives of the aortic arches. Soon after development, the first, second and the fifth aortic arches disappear completely.

The third aortic arch persists on each side as the *first part of the internal carotid artery* and the persisting dorsal aorta into which it opens forms the *remaining portion of the internal carotid artery.* Each of the third arches gives out a branch from its ventral part to form the *external carotid artery.*

The fourth aortic arches behave differently on the two sides. The right fourth aortic arch forms the *proximal part of right subclavian artery*—its distal part being formed by the right dorsal aorta (between the right fourth and seventh intersegmental arteries) and right seventh intersegmental artery. The left fourth aortic arch together with the aortic sac and the left dorsal aorta upto its fusion with the right dorsal aorta forms the *arch of the aorta.* The left seventh intersegmental artery is drawn up in the developing arch of the aorta and forms the *left subclavian artery.*

Each of the sixth aortic arches gives out a pulmonary branch. The left sixth aortic arch together with its pulmonary branch forms the *left pulmonary artery;* its remaining portion, that is, the portion between its pulmonary branch and its termination in the dorsal aorta forms the *ductus arteriosus.* The right sixth aortic arch together with its pulmonary branch forms the *right pulmonary artery*; its remaining portion, that is, the portion between the origin of the pulmonary branch and its termination in the dorsal aorta, disappears completely.

The remaining portion of the aortic sac is drawn apart and divided into right and left limbs which form the *innominate* and the *left common carotid arteries* respectively.

The dorsal aortæ. There are two dorsal aortæ, one on each side, and are placed side by side on the dorsal wall of the embryo on either side of the median plane. During early somite stage (fourth week) they begin as two tubes opposite the roof of the developing pharynx and then grow caudalwards providing branches to the structures all round. During the end of the fourth week, opposite the region from first thoracic to the first lumbar segment, the two dorsal aortæ are seen to fuse together to form a large single tube, the future *descending aorta.* Fusion proceeds further caudalwards and it extends upto the level of the last lumbar segment by the end of the fifth week. The median sacral artery of the adult represents the fused caudal portions of the dorsal aortæ.

Thus it appears that below the level of the first thoracic segment the two dorsal aortæ fuse together to form a single tube but above this level they remain unfused and attain further developmental changes which differ on the two sides.

Both the right and the left dorsal aortæ disappear between the third and the fourth aortic arches. Cranial to the third aortic arches both dorsal aortæ persist and together with the third aortic arch they form the future external carotid artery. The right dorsal aorta between its seventh intersegmental branch and its fusion with the left dorsal aorta disappears.

Branches of the dorsal aortæ—The branches from the dorsal aortæ may be grouped as follows:

(1) Intersegmental branches
(2) Ventral branches
(3) Lateral branches

(1) *Intersegmental branches.* These arteries, as their name implies, are 'intersegmental' in position and pass laterally between somitic segments; each artery divides into *dorsal* and *lateral branches.* The dorsal branch is destined to supply the spinal cord and its meninges while the lateral branch is destined to supply the body wall. In the thoracic region these lateral branches form the intercostal arteries while in the lumbar region they form the four lumbar arteries. The fifth pair in series in the lumbar region develop into the common iliac arteries.

In the neck region there are eight intersegmental arteries on each side and are numbered cranio-caudally. All these arteries are connected to each other by a longitudinal anastomosis. The seventh intersegmental artery represents the subclavian artery (see later) and soon the connections of the upper six intersegmental arteries with the dorsal aorta being retrogressed the longitudinal anastomoses (precostal anastomosis) between the intersegmental arteries form a longitudinal artery having a connection with the seventh intersegmental. This longitudinal

artery is the first and second portions of the future vertebral artery. The third portion of the vertebral artery, that is, the portion lying over the arch of the atlas is formed by the spinal branch of the first cervical intersegmental artery. The fourth or the intracranial part of the vertebral artery is formed by the neural division (forming preneural anastomosis) of the above spinal branch.

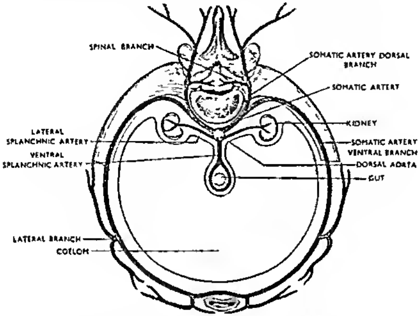


Fig 180. The dorsal aorta and its branches.

The lateral branches of the intersegmental arteries in the region of the trunk pass ventralwards along the segmental nerves and form a chain of longitudinal ventral anastomoses on either side of the median plane and from this chain of ventral anastomoses the internal mammary, superior and inferior epigastric arteries are derived.

(2) *Ventral branches.* The ventral branches of the dorsal aortæ are numerous originally but later on only three branches persist supplying the archenteron namely cœliac, superior mesenteric and inferior mesenteric. The site of origin of these branches migrates considerably caudalwards with the change and return of the gut tube within the abdomen. Thus the cœliac artery from its original site opposite the seventh cervical segment migrates to the level of the twelfth thoracic segment, the superior mesenteric fmm the level of the second thoracie to the first lumbar and the inferior mesenteric migrates from the level of the twelfth thoracic to the third lumbar segment.

(3) *Lateral branches.* The lateral branches from the dorsal aortæ are also numerous originally and are destined to supply the developing genito-urinary system (mesonephros, metanephros and the gonads). The persistent lateral branches are the renal, suprarenal and the testicular or ovarian arteries.

Summary of the developments of the great vessels (Arterial System)—

Ascending Aorta and the pulmonary trunk. Four endothelial cushions, right, left, ventral and dorsal, appear within the truncus arteriosus. The right and the left cushions meet together and split up the truncus arteriosus longitudinally into two great vessels, the ascending aorta behind and the pulmonary trunk in front.

Pulmonary artery. The right and the left pulmonary arteries are formed by the proximal portion of the corresponding sixth aortic arch together with the pulmonary branch. The distal portion, that is, the portion beyond the origin of the pulmonary branch, of the sixth aortic arch becomes obliterated on both the sides.

Arch of the aorta. The arch of the aorta is formed by contribution from the caudal part of left portion of the aortic sac, left fourth aortic arch and the left dorsal aorta upto its fusion with the right dorsal aorta.

Descending aorta. The descending aorta extends from the level of the eighth intersegmental branch upto the level of the fifth lumbar intersegmental branch and is formed by the fusion of the right and left dorsal aortae in this situation.

Common and internal carotid arteries. The third aortic arch together with the persisting dorsal aorta cranial to it forms the common and the internal carotid arteries.

Innominate artery. With the change in position of the heart the cranial portion of the aortic sac is drawn apart into right and left horns opposite the third arch arteries. The drawn out left horn contributes to the formation of the root of the left common carotid artery while the right horn develops into the innominate artery.

Subclavian arteries. The left subclavian artery is formed by the left seventh intersegmental branch of the left dorsal aorta. The right subclavian artery is formed by the right fourth aortic arch, right dorsal aorta between right fourth and seventh intersegmental arteries and a portion by the right seventh intersegmental artery.

External carotid. Originally there is no external carotid artery and later on it is formed by a branch budding off from the ventral root of the third aortic arch.

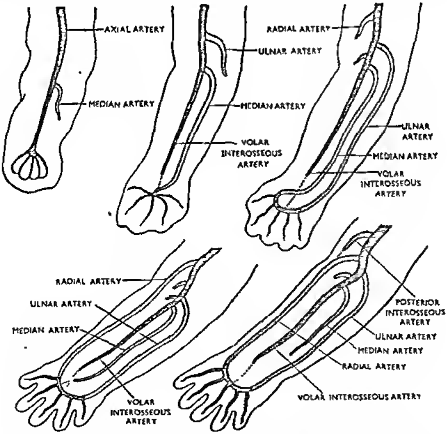


Fig. 181. Diagrammatic representations to show the axial artery of the upper limb, its stagewise modifications and the formation of the definitive arteries.

Arteries of the upper limb. During the fifth week of foetal life when the upper limb bud is in making, a network of capillary vessels from the seventh intersegmental artery extend into it. By the sixth week, definitive arteries are formed from the capillary plexuses resulting in the formation of the axial artery of the limb and by the end of the eighth week, almost all the vessels have appeared.

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The axial artery of the upper limb. The axial artery of the upper limb is the direct continuation of the seventh intersegmental artery or the subclavian artery and as it runs through the axilla and the arm, it goes by the name of axillary and brachial artery respectively. Then it runs through the elbow and forearm and ultimately ends in the capillary network in the palm.

Below the elbow the first branch that arises from the axial artery is known as the *median artery* which accompanies the median nerve and ends in the capillary plexus in the hand. The radial branch of the axial artery accompanies the radial nerve and arises from the brachial artery opposite the middle of the arm and is known as the *primary radial artery.* The *secondary* or *the definitive radial artery* arises from the brachial at the elbow and soon joins with the primary radial artery and then coursing through the foream it ends in the hand where it subsequently forms the deep plamar arch. The ulnar branch of the axial artery arises from the brachial at the elbow and by passing deep to the flexor muscle mass it descends vertically to enter into the palm of the hand and joins with the capillary network which subsequently develops into the superficial palmar arch. Below the elbow it also gives another branch, the posterior interosseous artery which passes backwards in between the bones of the forearm and then descends downwards on the back of the interosseous membrane.

Changes in the axial artery and its branches and formation of the definitive arterial system. The primary radial artery arising from the brachial in the centre of the arm, soon disappears from the level of its origin upto its union with the secondary radial artery and the secondary radial artery becomes the definitive radial artery. The axial artery in the forearm becomes much modified to form a slender artery, the *anterior interosseous artery* which passes in front of the interosseous membrane and ultimately loses its connection with the capillary network in the palm which is destined to form the deep palmar arch whereas the radial artery establishes connection with the same to feed the deep palmar arch. The median artery, which accompanies the median nerve soon undergoes retrogression and loses its connection from the capillary network in the palm into which the ulnar artery terminates subsequently to form the superficial palmar arch. Communications are also established between the superficial and the deep palmar arches and between the posterior interosseous artery and the deep palmar arch.

The arteries of the lower limb. The arteries of the lower limb appear almost simultaneously with the arteries of the upper limb. Here too, there develops primarily an axial artery which dominates as the main feeder stem during the earlier part, but soon the arterial pattern changes considerably which leads to the formation of the definitive arteries of the limb.

The axial artery of the lower limb. The axial artery of the lower limb arises from the secondary umbilical artery—the primary umbilical artery from the dorsal aorta having been migrated cranially the fifth lumbar intersegmental artery (common iliac) forms the secondary umbilical artery. After its origin the axial artery comes out of the pelvic cavity through the greater sciatic foramen and accompanying the sciatic nerve it passes to the back of the thigh beneath the hamstring muscle mass and reaches the region of the popliteal fossa. Then the artery passes between the popliteus muscle mass and the bone to gain the interosseous membrane. Following the interosseous membrane it enters into the sole of the foot where it ends in a capillary network from which a perforating branch passes to the dorsum of the foot and joins with a dorsal capillary network.

At the proximal part of the popliteal fossa the axial artery gives a communicating branch, the *ramus communicans superior*, which pierces through the hamstring muscle mass and establishes connection with the developing femoral artery. At the proximal border of the popliteus it gives two branches, the *primitive posterior tibial* and *personeal* which descend into the leg dorsal to the popliteus and the tibialis posterior muscles and ultimately join with the capillary network in the sole of the foot. At the lower border of the popliteus the axial artery gives a perforating branch which passes ventrally in between the two bones of the leg and after communicating with

the ventral capillary plexus from the femoral it descends through the ventral aspect of the leg and then along the dorsum of the foot as the anterior tibial and the arteria dorsalis pedis respectively. The distal portion of the popliteal artery formed by fusion of the proximal parts of the primitive posterior and the peroneal arteries gives

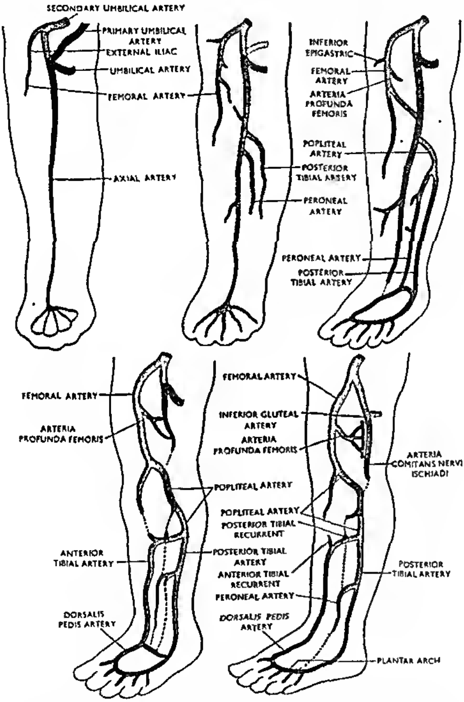


Fig 182. Diagrammatic representations to show the axial artery of the lower limb its stagewise modifications and the formation of the definitive arteries.

a communicating branch, the *ramus communicans medius* which joins with the axial artery below the popliteus opposite the origin of the anterior tibial from the axial artery. In the leg the primitive peroneal artery is connected with the axial artery by a communicating branch, the *ramus communicans inferior*.

Other accessory arteries. The secondary umbilical artery gives out a branch proxi-

mal to the origin of the axial artery known as the *external iliac artery* which descends downwards over the superior ramus of the pubis and enters into the thigh and becomes the *femoral artery*. A superficial plexus from the femoral descends downwards through the ventral aspect of the thigh and the leg and ultimately joins with the dorsal capillary network on the dorsum of the foot. In its course through the leg the capillary plexuses run together to form the *primary anterior tibial artery*.

Changes in the axial artery and its branches and formation of the definitive arteries of the limb. The proximal portion of the axial artery, though much modified, persists as the *inferior gluteal artery*. The portion between the arteria communicans superior and the persisting proximal part disappears completely. The portion between the popliteus and the arteria communicans superior persists and forms the *proximal portion of the popliteal artery*. The *distal portion of the popliteal artery* is formed by the fusion of the proximal parts of the primitive posterior tibial and the peroneal arteries. The portion of the axial artery between the popliteus and the bone disappears completely. A short segment of the axial artery immediately below the popliteus persists to contribute in the formation of the anterior tibial artery along with the arteria communicans medius from the distal part of the popliteus. The capillary plexus on the ventral aspect disappears above the knee. Thus the *anterior tibial artery* is formed by the arteria communicans medius, the persisting short segment of the axial artery below the popliteus, the perforating branch of the axial artery in this situation and by the primary anterior tibial from the ventral capillary plexus. The distal portion of the axial artery loses its connection with the plantar network and persists to contribute in the formation of the *distal part of the peroneal artery*. The proximal portion of the peroneal artery is formed by the primitive peroneal branch of the posterior tibial and by the arteria communicans inferior. The primitive peroneal artery disappears below the origin of the arteria communicans inferior. The proximal part of the posterior tibial is formed by the fusion of the proximal part of the primitive posterior tibial and primitive peroneal arteries, thus the latter gains its origin from the posterior tibial. The distal portion of the posterior tibial is formed by the persisting primitive posterior tibial and communicates with the plantar network which subsequently develops into the plantar arch.

THE VENOUS SYSTEM

Like the arterial system the venous system also begins as networks of venous capillaries and drain the blood from the arterial system to the primitive heart by means of primitive veins. There are four pairs of primitive veins namely anterior cardinal, posterior cardinal, umbilical and vitelline, which drain the whole body of the developing embryo into the primitive heart. The two anterior cardinal veins, right and left, drain the upper limb and the cranial end; the two posterior cardinal veins, right and left, drain the caudal part while those from the placenta are the right and left umbilical veins and those from the archenteron are the right and left vitelline veins. The anterior cardinal vein of each side joins with the corresponding posterior cardinal vein to form a common venous channel, the *duct of Cuvier*, which ends by opening into the *sinus venosus*, a common venous chamber attached to the caudal part of the primitive heart tube. The vitelline and the umbilical veins also open into the sinus venosus independently.

Anterior cardinal veins. These are two bilateral, longitudinal venous channels, one on each side, which drain blood from the upper limb and the cephalic end of the embryo into the sinus venosus through the two ducts of Cuvier, right and left. Each vein begins in the region of the developing eye, and by traversing through the developing head and the neck each ends in the region of the future thorax as above. Thus each anterior cardinal vein can be divisible into three parts *cranial*, *nuchal* and *thoracic*.

Cranial part. The cranial part of each anterior cardinal vein begins in the region of the optic stalk and then coursing dorsally and caudally it enters in the developing neck region. In its course it lies medial to the trigeminal ganglion, otic

vesicle and the cranial nerves from seventh to eleventh. After sometime, the portion of the anterior cardinal vein that lies medial to the otic vesicle and the cranial nerves disappear and a new venous channel is formed on the lateral side of the otic vesicle and the above cranial nerves. This new vein soon establishes its connection with the nuchal part of the anterior cardinal vein. This new venous channel also disappears at a later date. The portion of the anterior cardinal vein which now persists in the head-region is called the *primary head vein*. The primary head vein soon receives tributaries which are arranged into ventral and dorsal branches.

The *dorsal tributaries* of the primary head vein are arranged into three groups namely *anterior, middle* and *posterior*. The anterior tributaries drain the fore- and the mid-brain, the middle tributaries drain the cerebellum while the posterior tributaries drain the medullary regions. All these groups of tributaries are arranged in plexiform networks and from the networks of each group one stem vein emerges prior to its termination in the primary head vein. Thus, associated with the three groups of tributaries there appear three corresponding stem veins anterior, middle and posterior. Subsequently the middle and the posterior stem veins are joined together by a communicating vein and likewise the anterior stem vein also joins with the middle stem vein. Thus a common venous channel is formed connecting the three stem veins. Then the three stem veins are detached from their connection with the primary head vein and consequently this common venous channel is also detached from its connection with the primary head vein. The detached posterior stem vein then goes down and establishes communication with the nuchal part of the anterior cardinal vein which forms the internal jugular vein.

The persisting primary head vein that lies ventro-medial to the trigeminal ganglion and its ventral tributaries forms the *cavernous sinus* and the *ophthalmic veins* respectively.

The common venous channel linking the three stem veins is displaced postero-laterally by the developing brain and is subsequently transformed into the *transverse* and *sigmoid sinuses*. With the growth of the brain and its meninges the anterior and middle plexuses are also displaced dorsally (towards the top of the adult brain) and form a net work of venous plexus disposed dorso-ventrally. The venous network meets with its fellow of the opposite side to form a curtain of common venous network. Along the dorsal border of this venous network the veins run together to form an elongated vein, the *superior sagittal sinus* Similarly another elongated vein forms at its ventral border from which the *inferior sagittal* and the *straight sinuses* develop. The superior sagittal sinus ends by opening into the left transverse sinus whereas the inferior sagittal sinus ends by opening into the right transverse sinus through the straight sinus.

The detached middle stem vein between the common venous channel and the primary head vein, which still retains connection with the latter, at first undergoes atrophy and subsequently it is reformed as the *superior petrosal sinus* and is connected with the common venous channel which has now formed the transverse sinus. The *inferior petrosal sinus* is newly formed by extension of growth from the caudal end of the cavenous sinus and passes caudally to end into the internal jugular vein.

Nuchal and thoracic parts of anterior cardinal vein. In the neck region the anterior cardinal vein develops into the internal jugular vein and at the root of the neck it receives the main venous trunk, the subclavian vein, from the superior extremity.

As they enter the thorax the two anterior cardinal veins are joined together by a transverse venous channel. This tranverse venous channel subsequently develops into the *left innominate vein*. The portion of the right anterior cardinal vein between this tranverse venous channel and the right subclavian vein, develops into *right innominate vein*. The portion of the right anterior cardinal vein from the transverse venous channel to the commencement of the right duct of Cuvier, forms the extra-pericardial part of superior vena cava. The intra-pericardial part of the superior vena cava is formed by the right duct of Cuvier. The terminal part of the right posterior cardinal vein which opens into it forms the *terminal part of azygos vein*. The short segment of the left anterior cardinal vein caudal to the transverse venous channel

(left innominate vein) retrogresses considerably due to diversion of most of the blood from left to the right side through the left innominate vein and forms the terminal part of the *left superior intercostal vein.* The intra-pericardial part of left duct of Cuvier also atrophies and its cranial part forms the *ligament of the vena cava* and its caudal part forms the *oblique vein of the left atrium.*

According to Keith the left superior intercostal vein is a composite vein and represents three embryonic vessels, namely terminal part of left primitive jugular vein (left anterior cardinal vein caudal to the left innominate vein), extra-pericardial part of the left duct of Cuvier and the anterior part of the left posterior cardinal vein.

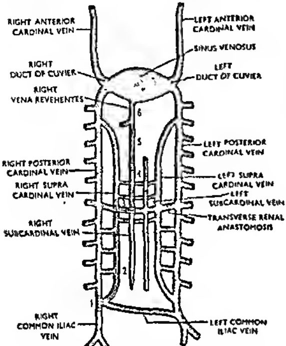


Fig 183. The posterior cardinal, subcardinal and the supracardinal veins

Note that different shades (numbered from below upwards) in the above venous systems indicate the different sources of origin of inferior vena cava

The posterior cardinal veins and the associated venous systems. Three venous systems, *posterior cardinal, subcardinal* and *supra-cardinal,* are found to develop in quick succession within the abdomen during fifth and sixth week of intrauterine life. They form the main venous channels draining the most of the parieties of the abdomen, the urogenital system and the lower extremities. Due to rapid growth changes each of these venous systems becomes extensively modified in their form and extent and a series of changes take place before the establishment of the definitive veins. The following is a brief account of the sequence of events in these venous systems:

The posterior cardinal veins are two in number, right and left, and each lies longitudinally on the dorsal wall on either side of the descending aorta. Each of these veins begins in the region of the base of sacrum by the union of the venous tributaries from the corresponding inferior extremity and from the sacral segments. Passing vertically cranialwards each vein joins with the corresponding anterior cardinal vein to form the *duct of Cuvier* which ends in the sinus venosus. In its course it receives tributaries from the lumbar and thoracic segments and from the developing mesonephros (Wolffian body).

During the sixth week of intrauterine life the venous networks from the gonads and the mesonephros on each side run together to form a longitudinal venous channel known as the *subcardinal vein* which terminates in the posterior cardinal vein. Then the two subcardinal veins are joined together by a transverse venous channel which passes in front of the descending aorta. The level at which the transverse anastomosis takes place is taken to be the "renal level" because at a later date this transverse venous channel is found to drain blood from the kidney. Subsequently both the pre-renal and post-renal segments of the left subcardinal vein completely retrogress; the post-renal segment of the right subcardinal vein also retrogresses but a part of its pre-renal segment persists and comes to the formation of a part of the inferior vena cava. A new venous channel soon appears at the cranial end of the persistent pre-renal part of the right subcardinal vein and this vein grows out cranially and soon establishes a communication with the vena hepatis communis.

With the above changes in the subcardinal venous system most of the

posterior cardinal veins on both sides disappear completely except their extreme caudal and cephalic ends.

With the disappearance of the posterior cardinal veins a new venous channel known as the *supracardinal vein* comes into being on each side between the subcardinal and the posterior cardinal veins and takes over the functions of the primitive posterior cardinal vein. It receives the segmental veins and joins with the persistent caudal end of the posterior cardinal vein. The supracardinal vein also joins with the renal transverse venous channel which joined the two subcardinal veins together. At the caudal end the transverse venous channel which joined the caudal ends of the two posterior cardinal veins becomes communicated to the supracardinal vein. Then the post-renal segment of the left supracardinal vein disappears and the transverse venous channel originally connecting the two posterior cardinal veins at their caudal ends, becomes the *left common iliac vein* which now communicates with the right supracardinal vein. The post-renal segment of the right supracardinal vein develops into the post-renal segment of inferior vena cava while its pre-renal segment persists to form the caudal part of the azygos vein; its cranial part is formed by the persistent cranial end of the right posterior cardinal vein. The pre-renal segment of the left supracardinal vein persists to form the *hemiazygos* vein; it joins with the cephalic end of the left posterior cardinal vein which persists to form the caudal part of the left superior intercostal vein, the latter opens into the hemiazygos. As the two supracardinals are also communicated together by two transverse anastomosing venous channels at the cranial part of their pre-renal segments the hemiazygos usually ends into the azygos.

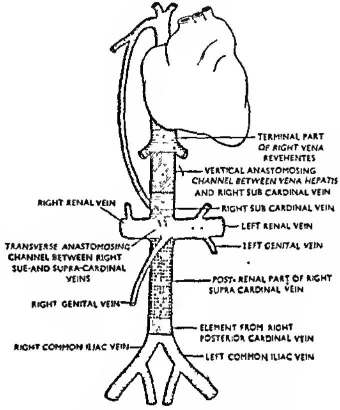


Fig. 184. The development of the inferior vena cava

Vitelline veins. The vitelline veins carry blood from the yolk sac and are two in number, right and left. Both the veins enter into the embryo at the cephalic margin of the umbilical orifice lying one on each side of the vitello-intestinal duct. Each vein at first terminates at the caudal end of the corresponding ventral aorta and when the caudal parts of the two ventral aortæ have fused together, it ends into the sinus venosus.

Each vein in its intra-embryonic course passes through the septum transversum where it is joined by the corresponding umbilical vein to form a common vitello-umbilical trunk which ends in the sinus venosus. Subsequently with the separation of the sinus venosus from the septum transversum the common trunk is absorbed into the sinus venosus and the two veins are seen to terminate in the sinus venosus individually and separately.

As the septum transversum is invaded by the liver diverticulum, both the vitelline and the umbilical veins get entangled within the developing liver which split them into numerous irregular inter-communicating blood spaces, the sinusoidal

tissue of the liver. Thus with the development of the liver within the septum transversum and with the isolation of the sinus venosus into the pericardium from the septum transversum the intra-embryonic course of the vitelline veins can be divisible into cranial, intermediate or intrahepatic and caudal parts.

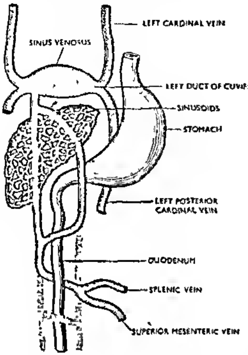


Fig. 185. The fate of the vitelline veins

The *cranial portion of each vitelline vein*, that is, the portion between the liver and the sinus venosus, is called the *vena revehens*. After sometime the left vena revehens loses its connection with the sinus venosus and migrates towards right side and ultimately joins with the right vena revehens. This common vena revehens (common hepatic) forms the terminal part of the *inferior vena cava*, and the intra-hepatic part of the right and the left vena revehens draining the liver form the corresponding *hepatic vein*.

The caudal part of each vitelline vein extends from the umbilical orifice to the liver. In this situation the two vitelline veins are joined together by three transverse venous channels and as the vitelline veins now lie one on each side of the duodenum the latter is transversely crossed by these venous channels. The cranial and the caudal transverse venous channels pass across the ventral aspect of the duodenum whereas the intermediate transverse venous channel passes dorsal to the duodenum.

The portion of each vitelline vein extending from the cranial transverse venous channel to the liver is called the *vena advehens*. The right vena advehens becomes the right branch of the portal vein whereas the left vena advehens together with the cranial ventral anastomosing channel forms the left branch of the portal vein.

Subsequently the left vitelline vein is joined by veins from the mid-gut and fore-gut tubes, that is, the superior mesenteric and the splenic vein respectively, opposite the intermediate dorsal anastomosing channel; retrogession occurs in both the vitelline veins together with caudal anastomosing channel caudal to the dorsal anastomosing channel, and in the left vitelline vein between the cranial and the intermediate anastomosing channels. Thus the venous channel that persists becomes the trunk of the portal vein. To be more precise *the portal vein is developed* by the persistence of a short segment of left vitelline vein opposite the dorsal anastomosing channel, the dorsal anastomosing channel itself and by the persisting right vitelline vein between the cranial and the intermediate venous anastomosing channels.

The intrahepatic or the intermediate parts of the vitelline veins form the hepatic sinusoidal tissues which form the link between the portal and the hepatic veins.

Umbilical veins. The vena umbilicalis impar is the main vein which carries oxygenated blood from the placenta and traversing through the umbilical cord it reaches the umbilical orifice where it divides into right and left branches, the right and left umbilical veins. Each of the umbilical veins lies ventro-lateral to the corresponding vitelline vein and passes through the septum transversum. At first each umbilical vein joins with the corresponding vitelline vein to form a common vitello-umbilical trunk which terminates in the corresponding horn of the sinus venosus. Subsequently when the sinus venosus migrates from the septum transversum into the pericardial sac the common vitello-umbilical trunk becomes

absorbed into the wall of the sinus venosus and consequently both the veins terminate individually into the sinus venosus.

In its course through the septum transversum each of the umbilical veins gets entangled within the developing liver and thus each vein may be divided into cranial part, intrahepatic part and caudal part. The intrahepatic parts of both the umbilical veins become converted into the hepatic sinusoidal tissues. Both the cranial and caudal parts of the right umbilical vein completely disappear. With the disapperance of the right umbilical vein the left umbilical vein becomes much enlarged. Its cranial part (that is the part between the liver and the sinus venosus) also disappears and the hepatic end of its caudal part becomes connected with the left vena advehens (which forms part of the left branch of the portal vein).

Thus the whole volume of blood from the placenta has got to pass through the hepatic sinusoids which means a tremendous load on them and therefore a direct new venous channel is formed which connects the left umbilical directly across the back of the liver with the right vena revehens which now forms the inferior vena cava. This new venous channel is called the *ductus venosus.*

To summarise, it may be mentioned that with the disappearnce of the right umbilical and the cranial part of the left umbilical veins, blood from the placenta after passing through the persisting left umbilical vein reaches the inferior vena cava mostly by the ductus venosus and partly through the hepatic sinusoids and hepatic veins.

After birth with the cessation of placental circulation the left umbilical vein becomes obliterated to form the *ligamentum teres hepatis,* and the ductus venosus, which also obliterates, becomes the *ligamentum venosum.*

URINARY SYSTEM

The urinary system consists of a chain of organs, namely the kidney, ureter, urinary bladder and the urethra which are concerned in the elimination of waste products from the body in the form of urine. Of the above, the kidney forms the main organ of production, the ureter, the organ of transport to the reservoir, the urinary bladder and the urethra forms the final organ of disposal to the exterior.

History in the development of kidney. Since very early part of development (fourth week of development) nature shows the signs of an attempt to form the excretory organ and after a series of frantic attempts towards the formation of the organ it succeeds in organising the definitive functioning kidney. The intermediate cell mass of intra-embryonic mesoderm occupies its position on the dorsal wall of the embryo in between the paraxial mesoderm and the lateral plate mesoderm and forms a continuous column of cell mass which extends from the cephalic to the caudal end of the embryo. It is this intermediate cell mass which shows successive regional growth activities from cephalic to caudal end, finally gives rise to the formation of the definitive kidney from its caudal part. At first the intermediate cell mass of the upper cervical region becomes thickened and shows changes comparable to the structures found in the excretory organ (kidney), and the tissues concerned in elaborating such changes are known as *pronephros.* Subsequently the pronephoros disappears gradually but the intermediate cell mass of the cervico-dorsi-lumbar region grows enormously and undergoes changes that lead to the formation of a type of excretory organ known as *mesonephros.* Ultimately the mesonephros also disappears but the intermediate cell mass in the region of the pelvic cavity (sacral region) undergoes proliferation to form the basis of the *metanephros* or the *definitive kidney.* Thus the formation of kidney involves a series of changes in the intermediate cell mass in which before formation of the metanephros or the definitive kindey, pronephros and mesonephros are formed and they disappear. The following is a brief outline about the sequence of events in those structures:

Pronephros. During the early embryonic life, that is, during fourth and fifth weeks of fœtal life the cells of the intermediate cell mass in the upper cervical region become segmented strictly in relation to the different segments of the body

to form cords of cells. These cords of cells are roughly disposed transversely and each of the cords turns downwards at its lateral end. The caudal portion of the downturned lateral end fuses the downturned lateral end of the succeeding cord of cells and in this way, when the last cord of cells is joined by its fellow just above it, a solid longitudinal tubular structure is formed known as the *pronephric duct.* Meanwhile the medial end of each segmented cord of cells fuses with the cœlomic epithelium and becomes canalised to open into the cœlomic cavity and this narrow canal is known as the *nephrostome canal.* Subsequently a branch from the dorsal aorta invaginates into the cœlomic cavity adjacent to the medial end of the nephrostome canal and thus representing the formation of a glomerulus. This type of glomerulus is called an *external glomerulus* because it has failed to connect itself with the nephrostome canal which now represents the nephrogenic tubules. Subsequently the caudal end of the pronephric duct proliferates to grow caudally and in its course it descends along the lateral side of the mesonephros which is now developing, and finally it reaches the cloaca in which it ends. *Pari passu* with the growth of the pronephric duct caudally, its cranial part as well as the pronephros itself degenerate and disappear.

In human subjects the pronephros forms a non-functioning element and the pronephric duct is formed by a solid cord of cells. The branch from the dorsal aorta which invaginates into the cœlom represents the external glomerulus (because it fails to invaginate into the pronephric tubule) which is a special feature of the pronephros in contrast to internal glomerulus of both mesonephros and metanephros.

Mesonephros. During the early part of development, the mesonephros is more extensive and occupies its position in the intermediate cell mass opposite the cervico-dorsi-lumbar region (from fifth cervical to the fourth lumbar segments) and its cephalic end overlaps the caudal end of the pronephros. At about the end of the eighth week a considerable portion of it has undergone atrophy and it forms a conspicuous fusiform swelling on the dorsal wall extending from the level of the tenth dorsal segment up to the lower border of the third lumbar segment. The fusiform swelling projects into the cœlomic cavity and forms a ridge-like elevation known as the *mesonephric ridge* on either side of the dorsal mesentery. On its medial side there lies the *genital ridge.* Both the genital and mesonephric ridges receive their dorsal attachment by a common mesentery, the *urogenital mesentery* and the pronephric duct descends caudalwards on its lateral side.

The mesonephros differentiates into a series of tubules which can be divisible into *mesonephric tubules* and *genital tubules.* The mesonephric tubules are most numerous and are secretory in function and each is invaginated at its medial end by a glomerular tuft formed by a branch from the dorsal aorta while its lateral end opens into the pronephric duct. The genital tubules are only few in number and are non-secretory in function. Each genital tubule is connected at its medial end with the genital cord and at its lateral end with the pronephric duct.

The mesonephric tubules. The cells of the mesonephros become segmented in a series of spherical blocks which soon become hollowed out to form the *mesonephric vesicle.* The number of the mesonephric vesicle is not strictly segmental in distribution like the pronephric tubules but there are usually more than one vesicle in each segment of the body. Later on, the cells at the lateral end of each vesicle grow out as cord of cells which soon become S-shaped and its free end joins with the pronephric duct which may now be called the *mesonephric duct.* The S-shaped solid cord of cells soon becomes hollowed out to form the mesonephric tubule which becomes continuous with the lumen of the mesonephric duct. The proximal part of each mesonephric tubule forms its secretory part while its distal portion constitutes the collecting part of the tubule. Meanwhile the medial aspect of each mesonephric vesicle becomes invaginated by a branch from the dorsal aorta which forms the glomerulus (internal) and the invaginated part of the vesicle forms the *Bowman's capsule.*

In some animals the mesonephros forms the permanent functioning excretory organ whereas in human subjects it is only temporarily functioning during the early part of its development.

The metanephros or the definitive or permanent kidney. The metanephros or the permanent kidney originates from dual sources. The secretory parts arise from the *nephrogenic cord* formed by the intermediate cell mass opposite the first and second sacral segments whereas its collecting parts are developed from the *ureteric bud* from the mesonephric duct.

During the fifth week of fœtal life the mesonephric duct just prior to its entrance into the cloaca gives a hollow outgrowth in the form of an evagination known as the *ureteric bud.* Then the ureteric bud extends dorso-laterally and assumes a bulbous end which invades into the nephrogenic cord opposite the first and second sacral segments. The nephogenic cord forms a cap-like investment over the bulbous end of the ureteric bud and is known as *metanephric cap or nephrogenic cap.* During

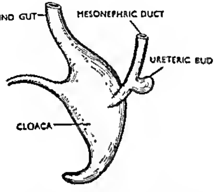


Fig. 186. The termination of mesonephric duct into cloaca and the formation of ureteric bud.

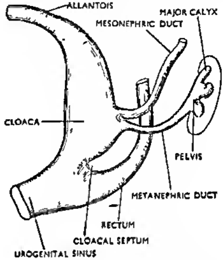


Fig. 187. A further stage of figure 186.

the seventh week, with further elongation of the ureteric bud, the metanephric cap together with the bulbous end of the ureteric bud is carried cranially to gain its position in the lumbar region where it lies dorsal to the mesonephros, and finally, at a later date, it assumes its normal position in the dorsi-lumbar region (from 11th thoracic to third lumbar vertebra). Meanwhile the bulbous end of the ureteric bud gives out two or three further outgrowths in the form of evaginations which form the *calyces majora.* Further evaginations from the latter form the *calyces minora* which subsequently give out the *primary* or *straight collecting ducts* and the other collecting portions of the renal tubules. Each straight collecting duct elongates considerably and protrudes into the metanephric tissue. Its distal end sends out a few (3 or 4) terminal evaginations which present an arched appearance and are known as *arched collecting tubules* of the collecting duct system. Each calyx minor with its straight collecting ducts together with the surrounding metanephric tissue constitutes the formation of the rudiment of the future *renal lobe.* The metanephric cap which invests the primordial evaginations from the ureteric bud, bulges out separately with each ureteral evagination and thus presenting a lobulated appearance (lobulated kidney). Later on the metanephric cap differentiates into secretory tubules (Bowman's capsules, 1st convoluted tubule and loop of Henle) and each of the tubules is invaginated by a glomerulus exactly in the same way as the mesonephric tubule. Then the secretory tubule derived from the metanephric tissue forms an S-shaped structure around each of the arched collecting tubule and subsequently the secretory tubules become continuous with the collecting tubules (formed out of the ureterie bud) which are massed into the renal pyramids. With further growth the fissures in between the lobules are closed up by growth of cortical substances from the contiguous sides and thus the primary lobulated character of the kidney disappears and the smooth outline of the normal kidney is established.

The metanephric tissues around the collecting systems from the ureteric bud divides into inner and outer zones. The cells of the inner zone differentiate into

secretory tubules (renal unit) whereas the cells of the outer zone form the *interstitial connective tissues* and *the renal capsule.*

The arterial system of the developing kidney falls into two groups, *temporary* and *permanent.* While in pelvic position the temporary arteries supplying the nephrogenic tissue are those which are derived from the dorsal aorta and the common iliac artery. While lying dorsal to the mesonephros the mesonephric blood vessels in

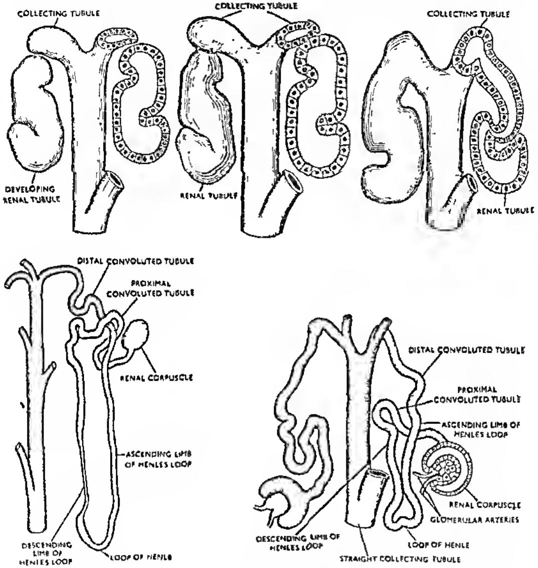


Fig. 188. Development of the secretory and collecting parts of the metanephric kidney.

series from eleventh thoracic to the fourth lumbar segments invade the growing kidney and form its second set of temporary blood vessels. Finally all the temporary blood vessels disappear except those opposite the second lumbar segment which form the definitive or the permanent arteries of the kidney.

THE ANOMALIES IN THE DEVELOPMENT OF KIDNEY :

(1) **Anomaly of position.** The ureteric bud may fail to lengthen or its growth may be misdirected leading to the formation of the kidney within the pelvic cavity —*pelvic kidney.* The discoid kidney usually lies in front of the vertebral column

opposite the bifurcation of the abdominal aorta. It may also lie either in front of the sacral promontory or in front of the sacro-iliac articulation. Occasionally the kidney occupies its position in the iliac fossa.

(2) **Anomaly of form.** (*a*) The fissures in between the lobules of the developing kidney may fail to close up resulting in producing the *lobulated kidney.*

(*b*) The nephrogenic cord of one side may fuse with the fellow of its opposite side either at their caudal (usual) or at their cephalic end across the median plane to give rise to the formation of *horse-shoe-shaped kidney.* The horse-shoe-shaped kidney is usually supplied by multiple segmental arteries.

(*c*) Sometimes in cases where two kidneys are fused together at their poles a single *elongated kidney* is formed on one side of the vertebral column, the hilum of the kidneys being directed on the same side.

(*d*) Occasionally two kidneys are fused at their poles in such a way so that the hilum of one being directed diametrically opposite to that of the other and thus giving rise to the formation of *S-shaped kidney.*

(*e*) Occasionally two kidneys may be found fused together opposite their hilum giving rise to a single *discoid kidney.*

(*f*) Occasionally the two fused kidneys may present an *irregular form.*

(3) **Anomaly of fusion.** The collecting tubules developed from the ureteric bud may fail to fuse with the secretory tubules developed from the nephrogenic tissue giving rise to the formation of *polycystic kidney.*

(4) **Anomaly of formation of ureteric bud.** The ureteric bud may divide to give rise to *forked ureter* or more than one ureteric bud may form to give rise to *double* or *triple ureters.*

(5) **Anomaly of number.** The nephrogenic element may be divided into two portions giving rise to two kidneys in each side. Occasionally there may develop only one kidney or rarely the two kidneys may fuse together to form one fused kidney.

(6) **Vascular anomalies.** Vascular anomalies of indefinite pattern are usually associated with the fused kidneys. Change in position of the kidney is also associated with change in its vascular supply. Thus when it is pelvic in position the kidney derives its blood supply from either the iliac arteries or from the bifurcation of the abdominal aorta. Vascular anomalies in case of a normal kidney may also occur in the form of aberrant renal arteries.

The urinary bladder. The urinary bladder has two sources of origin. The greater part of it is formed by the ventral part of the cloaca (entodermal) while a small part, the trigonal area, is developed from the fused caudal ends of the mesonephric ducts and from the median septum (mesodermal) into which they are embedded and which subdivides the cloaca into ventral and dorsal parts.

At the caudal part of the embryo the hindgut ends in a pouch-like dilatation known as the *cloaca* at the ventral end of which the allantois opens, and dorso-laterally, the two mesonephric ducts, one on each side, open. The mesonephric ducts are embedded into a median mesodermal septum known as the *cloacal septum* which extends from the dorso-lateral aspect of the hindgut and intervenes between the allantois and the hindgut. The cloacal septum extends cranio-caudally and divides the cloaca into *ventral* and *dorsal portions.* The ventral portion constitutes the *urogenital sinus portion of the cloaca* and into it the mesonephric ducts and the allantois open. The mesonephric duct just prior to its entrance into the urogenital sinus gives out the ureteric bud which subsequently develops into the ureter and the collecting portions of the renal tubules.

After subdivision of the cloaca the growth activities become more manifested in the urogenital sinus opposite the region of the openings of the mesonephric ducts and as a result, the ureteric bud arising out from the mesonephric duct becomes embedded within the urogenital sinus and the adjacent portion of the mesonephric duct becomes an U-shaped loop and is displaced dorso-caudal to it. Ultimately

the ventral limb of the U-shaped loop of the mesonephric ducts become absorbed into the wall of the urogenital sinus—its dorsal loop gaining its fresh attachment more caudally into that portion of the urogenital sinus which is destined to form the urethra. The portion of the urogenital sinus between the allantois and the upper limit of the openings of the mesonephric ducts grows out of proportion to the rest, and finally develops into the urinary bladder. The portion caudal to it containing the openings of the mesonephric ducts does not show much growth activity and remains as it is to form the prostatic portion of the urethra (up to the openings of the ejaculatory ducts) in the male, and in the female, the whole of the female urethra. The allantois undergoes retrogression to form the urachus.

The Urethra. The urethra *in the female* is formed by the urogenital sinus portion of the cloaca beyond the opening of the mesonephric duct into it.

In the male the urethra up to the opening of the ejaculatory duct is formed by the urogenital sinus portion of the cloaca (entodermal); between this point and the glans penis the urethra is formed by fusion of the urethral folds (entodermal) while the glandal part of the male urethra is formed by canalisation of an ectodermal cord of cells that penetrates through the glans.

Fate of the Mesonephros. At about the fifth week of fœtal life degeneration starts at the cephalic end of the mesonephros and the process gradually extends caudally until the ninth week when only some remains of the mesonephric tubules and persistence of some genital tubules exist.

In the female. The persistence of a few of the genital tubules of the Wolffian body in the female occupy their position within the mesosalpinx in between the ovary and the uterine tube and give rise to the formation of the *epoöphoron*. A few of the mesonephric or Wolffian tubules that persist lie between the ovary and the uterus within the broad ligament and form the *paroöphoron*.

In the male. The genital tubules to the mesonephros in the male persist and effect the union between the genital gland and the mesonephric duct and give rise to the formation of the *vasa efferentia* and *coni vasculosi*. The remnants of some of the Wolffian tubules are found in the globus minor or the tail of the epididymis and in the cord. In the globus minor they form the *vasa aberrantia* whereas in the cord, above the head of the epididymis, they form the *paradidymis* (organ of Giraldes).

The *vasa aberrantia* forms a blind tube connected with the tail of the epididymis or the globus minor and may be found to be extending upwards in between the body of the epididymis and the commencement of the vas deferens. Developmentally it forms a mesonephric tubule that has failed to establish connection with the genital gland but has done so with the mesonephric duct. The *paradidymis or the organ of Giraldes* may be found in association with the vas deferens in front of the lower part of the cord just above the head of the epididymis as a sessile swelling. It represents the remnants of the caudal portion of the mesonephros.

The *appendix of the testis*, a small sessile body on the top of the testis under cover of the globus major or the head of the epididymis, forms the embryonic remnants of the free end of the paramesonephric duct and represents the fimbriated end of the uterine tube of the female in the male. The *appendix of the epididymis*, a sessile body found to be attached on the top of the head of the epididymis, is formed by the blind upper end of the mesonephric duct.

The fate of the mesonephric or the Wolffian duct. *In the female.* The Wolffian duct in the female usually disappears completely in its cranial part; occasionally its caudal part persists as the *duct of Gartner*. Its blind cranial end occasionally may be persistent to form a *hydatid* or a sac-like dilatation which remains attached to the mesosalpinix at the fimbriated end of the uterine tube. When it is present it may become the site of cyst formation occasionaly.

The *duct of Gartner* when persists, extends along the sides of the body of the uterus : the cervix uteri and then prolongs further downwards along the ventrolateral of the vagina and ends by opening into the vestibule just beyond the hymen.

In the male. The Wolffian duct persists in the male and the following structures are derived from it:

(1) The head, body and the tail of the epididymis.

(2) Vas deferens.

(3) Seminal vesicles.

(4) Ejaculatory duct.

(5) Ureter and the collecting part of the renal tubules.

(6) Appendix of the epididymis.

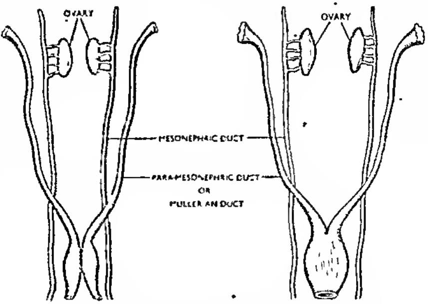


Fig. 189. Diagrammatic representations to show the relations of the paramesonephric and the mesonephric ducts and the formations of the uterus and the uterine tubes

The origin and fate of the paramesonephric or the Müllerian duct. During the sixth week of fœtal life the cœlomic epithelium ventrolateral to the cranial end of the mesonephros becomes invaginated in the form of a funnel. Solid growth from the apex of this funnel-shaped invagination extends caudalwards within the Wolffian ridge on the lateral side of the Wolffian or the mesonephric duct.

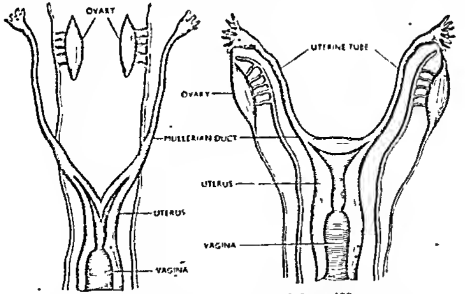


Fig. 190. A further stage of figure 189.

This solid tubular growth forms the *paramesonephric duct.* As the paramesonephric duct reaches the pelvic cavity it crosses ventral to the mesonephric duct to gain its medial side and approaches the fellow of its opposite side. The two paramesonephric ducts thus lie side by side in contact with the mesonephric duct lying laterally. The paramesonephric ducts then form a median mesodermal condensation to form the *genital cord.* Finally, they open into the dorsal wall of the

urogenital sinus portion of the cloaca in between the openings of the mesonephric ducts. Then the pelvic portions of the two paramesonephric ducts become canalised and then fuse with each other—the process taking place in a caudo-cranial direction to form the utero-vaginal canal. Until the end of the seventh week the nature of development of the paramesonephric ducts as described above persist in both the sexes. Subsequently, differentiation in growth of the ducts becomes drastically changed in the two sexes.

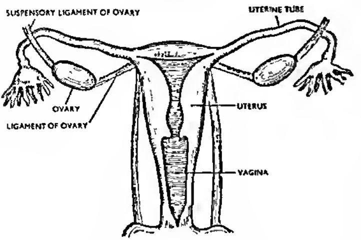


Fig. 191. A further stage of figure 190.

In the male. They almost completely disappear except their extreme cephalic and caudal ends. Its cephalic end forms the appendix of the testis whereas *its caudal* end forms the prostatic utricle which represents the uterus and the vagina in the male.

In the female. The Müllerian or the paramesonephric ducts in the female show marked growth activities and persist in their entire length to form the uterine tube, uterus and vagina (for details see genital system).

THE GENITAL SYSTEM

The genital system coosists of the genital glands, the genital ducts, the genital passages and the external genitalia, all of which, though indistinguishable sexually until sometime during the early part of development, acquire sexual differences in the two sexes at a later date.

The Gonads or the undifferentiated Genital Glands. At about the fourth week of fœtal life the mesothelium (lining cells of the peritoneum) on the ventromedial aspect of the mesonephros on each side proliferates rapidly so as to form a conspicuous swelling, the *gonad* or the *undifferentiated genital gland*. As the gonad gains in bulk it is seen to be connected with the mesonephros by a fold of peritoneum known as the *genital mesentery* and both the mesonephros and the gonad are connected to the dorsal wall by a common mesentery, the *urogenital mesentery*. Thus the urogenital mesentery together with the genital gland and the mesonephros resemble an Y-shaped swelling, the stem of the figure representing the urogenital mesentery, the medial limb, the gonad with its mesentery whereas the lateral limb representing the mesonephros with its mesentery. Further development of the gonads results in the differentiation of the genital glands with sexual characteristics. In the male it develops into testis whereas in the female it develops into ovary.

The Testis and its duct. The gonad of each side in the male develops into testis and the genital mesentery attached to it is called the *mesorchium*. Sexual characteristics in the gonad cannot be identified until seventh week when with appearance of the tunica albuginea, in case of testis, the sexual characteristics are difinitely established histologically.

The epithelial cells (mesothelium) covering the ventro-medial aspect of the mesonephros proliferate rapidly and grow into the subepithelial mesodermal tissue. The underlying mesodermal tissue develops into fibrous bands which invade into the growing epithelial bud and split it into cords of cells known as the *testis cords*. The testis cords become looped, tortuous and anastomose with one another freely and converge towards the mesorchium where they form networks of cords with-

in a mass of fibrous tissue. Meanwhile, during the seventh week, the mesodermal tissue subjacent to the epithelium develops into a tough membranous structure which surrounds the cords of cells. This membrane forms the *tunica albuginea*. The network of testis cords opposite the mesorchium forms the *rete testis* and the fibrous mass, within which the rete is entangled, forms the *mediastinum testis*. The testis cords then differentiate into *seminiferous* and *straight* tubules. The testis cords are at first solid cords of cells and subsequently during the sixth month they become canalised and acquire their lumen. Concurrently with the appearance of the lumen in the testis cords well-defined fibrous septa are seen to develop which subdivide the testis into different compartments or lobules. During the process of development some of the epitheloid cells get detached from the testis cords and these isolated epitheloid cell forms the *interstitial cells* of the testis. Of the three coverings of the testis the most superficial one is formed by the tunica vaginalis which represents the peritoneal covering of the gonad; the tunica albuginea develops *in situ* by differentiation of the subepithelial mesodermal tissue (already described) whereas the tunica vasculosa is formed by the intricate vascular plexus derived from the vessels supplying the organ.

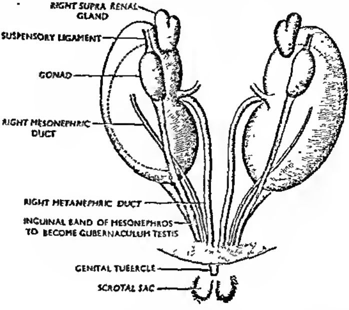


Fig. 192. Diagrammatic representations to show the *gonad, mesonephros, suprenenal gland and their relations.*

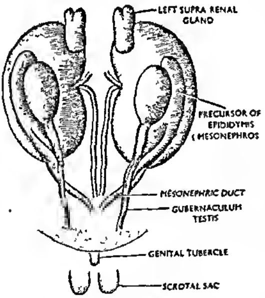


Fig. 193. A further stage of figure 192.

The gonads receive a series of blood vessels from the dorsal aorta but that which arises from the level of the *12th dorsal* segment persists to form the testicular artery. It receives its nerve supply from the *tenth dorsal segment* of the spinal cord.

During the third month of fœtal life the genital tubules of the mesonephros effect a connection with the rete testis and form the vasa efferentia whereas the canal of the epididymis and the vas deferens being formed by the mesonephric duct.

Descent of the testis. As growth follows and the embryo gains in length the gubernaculum testis which shows less growth activity becomes relatively shortened. Its lower end having extensive attachment, acts as a fixed point and, as the gubernaculum testis gradually shortens, it drags down the testis, the peritoneum and the mesonephric duct. A balanced traction from different strands of the gubernaculum testis drags the testis, peritoneum and the mesonephric duct through inguinal canal into the scortal sac. The peritoneum being dragged, a tubular peritoneal pouch known as the *processus vaginalis* is formed and precedes the descent of the testis and its duct into the scrotum. Later on, the walls of the neck of the

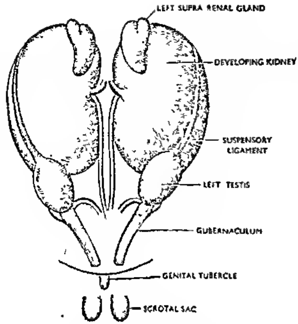


Fig. 191. A further stage of figure 193.

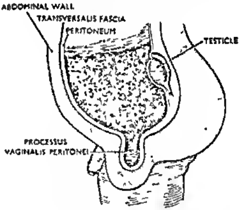
processus vaginalis fuse together and the canal is obliterated in its segment that lies within the inguinal canal while its distal blind scrotal segment persists to form the serous covering of testis —the tunica vaginalis.

During the third month of fœtal life the testis comes down to the iliac fossa, during the seventh month, into the inguinal canal, and finally it reaches the bottom of the scrotum at or soon after birth.

Applied Anatomy.—Due to defective traction the testis may not come out of the abdominal cavity at all or it may be lodged somewhere in the inguinal canal or it may descend into the inner side of the thigh or its complete descent may be unusually delayed.

Collection of serous fluid within the serous covering of the testis, tunica vaginalis, gives rise to enlargement of the scrotum causing a condition known as *hydrocele*. When the fluid collects in between the parietal and visceral layers of the tunica vaginalis it is known as the *vaginal hydrocele*. In some cases the processus vaginalis remains patent and a collection of fluid into a patent vaginal sac is known as the *congenital hydrocele*. In some cases the processus vaginalis is shut off from the peritoneal cavity but it remains patent below and a collection of fluid into the vaginal sac under this condition is known as the *infantile hydrocele*. Here the scrotal swelling extends upwards along the spermatic cord. Sometimes the processus vaginalis is obliterated both at the deep inguinal ring and opposite the head of the epididymis but remains patent in the intermediate portion and a collection of fluid into this patent sac is known as the *encysted hydrocele of the cord*. Sometimes a localised swelling on the head of the epididymis is known as the *encysted hydrocele of the epididymis* or *spermatocele*.

The ovary and its duct. Until seventh week the genital ridge develops in the same way in both the sexes. During seventh week sexual differences become manifested with the development of a well formed and thick tunica



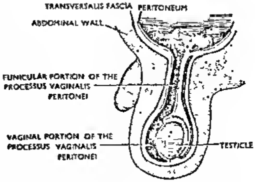


Fig. 195 The processus vaginalis and the descent of the testis (early stage).

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albuginea in case of the male genital gland (testis) whereas in the female genital gland (ovary) this is insignificantly thin and ill defined.

The cellular cords from the surface epithelium that invade the underlying stroma are known as *medullary cords*. The cells of the medullary cords contain, amongst ordinary epithelial cells, a few germ cells which are usually larger than the former. Each of the germ cells is surrounded by the smaller epithelial cells in the form of a follicle, the *primordial follicle*. The primordial follicle receives an investment from the stroma which constitutes the theca folliculi. Thus the developing ovary is seen to contain numerous primordial follicles embedded in a mass of stroma and is surrounded by a layer of the proliferating germinal epithelium, because no capsule of the nature of tunica albuginea develops beneath the surface epithelium.

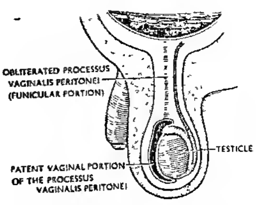

Fig. 196 The processus vaginalis and the descent of the testis (late stage).
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The unfused lumbar portion of the para-mesonephric duct, which forms the uterine tube, lies beside the genital ridge, becomes attached to the developing ovary by its cranial end and constitutes the oviduct or fallopian tube.

THE EXTERNAL GENITALIA AND THE GENITAL TRACT

The external genital organs up to certain stage of development (seventh week ?) remain undifferentiated and subsequently sexual characteristics appear and the sexes become distinguished owing to differential growth in the two sexes. In both the sexes, the external genital organs are fashioned in relation to the cloacal membrane as a result of changes both in and around this structure. It is known that the cloacal

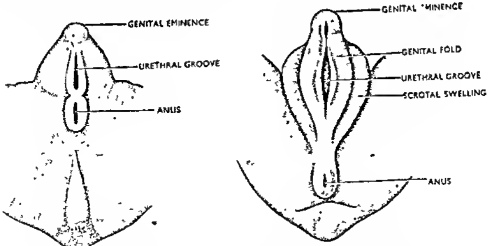

Fig. 197. Diagrammatic representations of the stages in development of the external genitalia in the male.

membrane is formed by the fusion of the ectoderm and the entoderm at the caudal end of the embryo, and surrounding the cloacal membrane the mesodermal tissue intervenes in between the ectoderm and the entoderm. At about the end of the fifth week the mesodermal tissue at the ventral end of the cloacal membrane becomes thickened to form an elevation known as the *genital tubercle*. Similarly,

the mesodermal tissue on either side of the membrane also becomes thickened to form a rim-like elevation known as the *inner genital fold.* Subsequently, at about the seventh week, the cloacal membrane gives way and the cloaca becomes communicated with the exterior. Meanwhile the urogenital septum has grown sufficiently to isolate the bladder from the rectum. The fissure which communicates

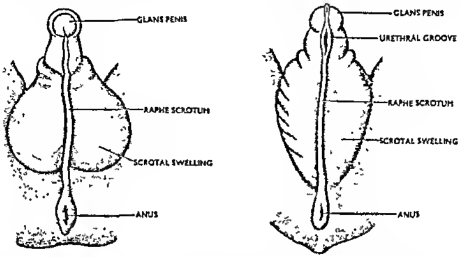

FIG. 198. Diagrammatic representations of the stages in development of the external genitalia in the male.

the cloaca externally is known as the urogenital cleft which is bounded on either side by the inner genital folds. At about the eighth week another bilateral swelling appears lateral to or outside the inner genital fold and is known as the *outer genital fold* or the *cloacal fold* or the *genital swelling*.

In the male. The genital tubercle rapidly elongates with a patch of ectodermal tissue at its free end. The urogenital sinus extends along the ventral surface of this elongated genital tubercle as a groove, the margins of which become continuous with the inner genital folds. The inner genital folds, which form the margins of the urogenital cleft, then unite opposite the median plane to form a continuous canal, the urethra (prostatic portion lying above the ejaculatory ducts, bulbous and penile portions lying below the opening of the ejaculatory ducts). The outer genital folds on either side also fuse in the median plane to form the *scrotum*. The ectodermal cap on the free end of the genital tubercle develops into the ectodermal epithelial lining of the *glans penis* and the line of fusion between the glans and the body of penis being marked by the coronal sulcus and the fold of skin that is reflected from it on the surface of the glans forms the *prepuce*. A cord of ectodermal tissue bores through the centre of the developing glans from its tip. This becomes canalised and forms the *glandal portion of the urethra*. The glandal portion of the urethra subsequently becomes continuous with the entodermal urethra formed by the fusion of the genital folds.

In the female. The genital tubercle remains rudimentary and forms the *clitoris*. The inner genital folds remain unfused to form the *labia minora*. Secondary growth from the ventral ends of the labia minora forms the *prepuce* and the *frenum*. The outer genital swelling remains unfused mostly to form the *labia majora* on either side while their dorsal ends fade away in the surrounding tissue. The posterior ends of the inner genital folds meet within the urogenital depression to form the *fourchette*. The unfused urogenital cleft forms the *vestibule of the vagina* and *the bulb of the vestibule* into which the urethra opens.

Formation of the uterus and the vagina. The pelvic portion of the para-mesonephric or the Mullerian ducts meet together opposite the median plane within the genital

cord during the early part of the third month of fœtal life. The walls of the two Mullerian ducts lying in contact with each other fuse together in most of their extent opposite the intermediate situation and remain unfused for a small extent both at its caudal and cranial ends. The fusion results in the formation of a single canal

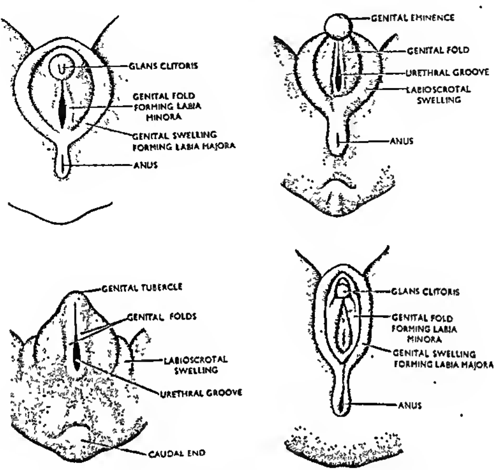

Fig. 199. Diagrammatic representations of the stages in the development of the external genitalia in the female.

known as the *utero-vaginal canal* at the both ends of which the two Mullarian ducts still remain unfused. The utero-vaginal canal gives rise to the formation of the body and the cervix of the uterus and the upper $\frac{2}{3}$ of the vagina. The fundus of the uterus being formed by the fusion of the two Mullarian ducts at the cranial end of the utero-vaginal canal at a later date. The unfused portions of the Mullarian ducts at the caudal end of the utero-vaginal canal form two cords of cells, the *vaginal cords* and each ends in a bulbous termination, the *vaginal bulb* which comes in contact with the wall of the urogenital sinus. The vaginal cords of cells grow out and elongate pushing the wall of the urogenital sinus. Subsquently the central portion of the caudal ends of the Mullerian or the vaginal bulbs penetrate through the wall of the urogenital sinus and reach the pudendal cleft or the opening of the urogenital sinus. At a still later date the vaginal cords fuse together and the central portion of the fused vaginal cords undergo dissolution and thereby forming the lower-third of the vaginal canal and the opening of the hymen. When the vaginal bulb pushes the wall of the urogenital sinus in front of it, some of the mesodermal element which surrounds the vaginal bulb intervenes between the vaginal bulb and the wall of the urogenital sinus. This mesodermal element together with the wall of entodermal urogenital sinus which lies in front of the vaginal bulb gives rise to the formation of the *hymen*.

CENTRAL NERVOUS SYSTEM

The central nervous system develops earlier during presomite stage from the embryonic ectoderm which differentiates into a condensed elongated area in front of the Hensen's node opposite the axial region of the body. This elongated area of ectodermal condensation is known as the *neural plate* which overlies the notochord and the medial portions of the paraxial mesoderm, and extends cranially as far as the cranial end of the notochord. The margins of the neural plate then grow more rapidly than its central portion and they become raised above the general level of the surface ectoderm to form the *neural folds*. The groove formed between the margins of the neural folds is called the *neural groove*. The neural groove then gradually deepens and elongates with the elongation of the body. Due to differential growth, its cranial end becomes broader and bilobed so as to form two bilateral elevations. By the seventh somite stage the two lateral margins of the neural groove meet together dorsally opposite the region of the fourth to the sixth somites to form the *neural tube*. By fourteenth-somite stage the margins of the unclosed portion of the neural groove fuse together completely both cranially and caudally except opposite its extreme ends. The open ends of the neural tube are called *neuropores*, that opposite the cranial end is called *anterior neuropore* while that on the caudal side is called the *posterior neuropore*.

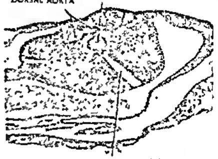

Fig. 200. A transverse section of a developing embryo (microphotograph). Note the position of the neural tube, notochord and dorsal aorta

At this stage the portion of the neural tube from the anterior neuropore to the level of the caudal part of the fourth somite constitutes the primordium of the future brain and the rest of the neural tube forms the primordium of the spinal cord.

By twentieth-somite stage the neuropores are closed completely. Before closure of the neuropores the caudal portion of the neural tube communicates temporarily with the hind-gut through the neurenteric canal.

After completion of its formation the neural tube becomes separated from the surface ectoderm and a chain of ectodermal cells appears in the angle between the surface ectoderm and the neural tube and this chain of ectodermal cells is called the *neural crest*. The neural crest provides the basis of formation of the sensory ganglia of the spinal and cranial nerves, sympathetic ganglia, chromaffin organs and the neurolemma sheath of the nerves.

The bi-lobed anterior part of the neutral plate which extends cranially beyond the notochord, later on, becomes the fore-brain or the prosencephalon, the narrow band behind it up to the first somite, becomes the mid-brain or the mesencephalon and the cephalic part of the rhombencephalon, while the remaining portion up to the level of the caudal part of the fourth somite becomes the caudal part of the hind-brain or the rhombencephalon. At this stage, on either side of the region of the mesencephalon and the cephalic part of the rhombencephalon, is a thickened ectodermal condensation known as the *otic placode* from which, subsequently, the internal ear develops. Behind the future prosencephalon the still exposed anterior end of the neutral plate becomes thickened which forms the primordia of the thalamic region. The optic groove on either side of the thalamic region becomes a lateral diverticulum known as the *optic vesicle* of the prosencephalic cavity.

As soon as the anterior neuropore is closed the brain end of the neutral tube shows three well defined dilatations, one opposite the prosencephalon, one opposite the mesencephalon and one opposite the rhombencephalon and are called the prosencephalic, mesencephalic and the rhombencephalic cavities respectively.

Subsequently owing to differential growth in the three primary vesicles and

with the formation of head fold, three flexures develop which are known as *primary brain flexures.* During the fourth week of fœtal life the first primary brain flexure appears opposite the region of the mid-brain and is known as the *mid-brain flexure.* Soon after the appearance of the mid-brain flexure the second primary flexure known as the *cervical flexure* appears between the spinal cord and the mid brain. In this flexure the spinal cord makes almost a right angle with the hind brain. The third primary flexure known as the *pontine flexure* appears last opposite the future pontine region, and presents a convexity forwards in constrast to the first two flexures having concavity forwards. The limiting sulcus on either side of the spinal cord which divides each half of the spinal cord into basal and alar laminæ, also extends into the hind- and mid-brain along their lateral aspects and subdivides them into ventral or basal and dorsal or alar laminæ.

Of the three primary brain vesicles the first primary brain vesicle is the earliest to develop and even prior to its development the primordia of their optic evaginations make their appearance at the junction of the fore-brain and the mid-brain. By a process of differential growth the cerebral hemispheres, corpus striatum and the thalamus are differentiated later on from the primordium of the fore-brain and the cavity of the first brain vesicle becomes modified to form the lateral and third ventricles. From the second primary brain vesicle the mid-brain and its cavity, the cerebral aqueduct, develop while from the third brain vesicle the pons, medulla oblongata, and cerebellum are developed. The cavity of the hind-brain vesicle becomes the fourth ventricle.

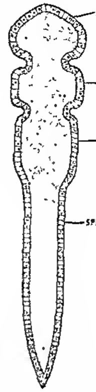

Fig. 201. A diagrammatic representation to show the changes in the neural canal that mould it to the formation of the brain and the spinal cord.

TELENCEPHALON

The telencephalon or the fore-brain consists of the cerebral hemispheres and they appear as two evaginations from the primary brain vesicle during the sixth week of fœtal life. Soon after, these evaginations or cerebral vesicles gain in bulk in all directions except opposite the floor plate where they form two small thickenings, the primordia of the corpus striatum. The portion of the brain tube just caudal to the cerebral vesicles is formed by the diencephalon which, at this stage, is completely hidden from view by the developing cerebral vesicles. The mesodermal tissue surrounding the brain vesicles shows differential growth opposite the median plane and dips into the cleft formed between the developing cerebral vesicles opposite the median plane and forms a partition, the future *falx cerebri*, which demarcates the cerebral vesicles into two cerebral hemispheres. This demarcation into cerebral hemispheres starts at first posteriorly and then gradually proceeds forwards. The medial surface of each cerebral hemisphere is very thin at this stage and a vascular mesodermal tissue at the posterior end invaginates into the cavity of the hemisphere pushing in front of it the thin medial wall of the hemisphere. This vascular mesodermal tissue later on differentiates into the choroid plexus of the lateral ventricle and the fissure formed by the invagination is the choroidal fissure which extends as far forwards as the interventricular foramen.

Corpus Striatum. Concurrently with the above changes the strial primordium opposite the floor of each cerebral vesicle has gained much in thickness and bulges into the cavity of the brain vesicle (lat. ventricle), subsequently the developing fibres coming to and from each hemisphere pass through the strial body and split it into ventro-lateral and dorso-medial parts. The ventro-lateral part develops into the *lentiform nucleus* whereas the dorso-medial part forms the *caudate nucleus;* the

traversing fibres between them become the *internal capsule.* The internal capsule together with the lentiform and caudate nuclei presents a striated appearance due to the white fibres traversing through the darker nuclei and the whole mass is known as the *corpus striatum.*

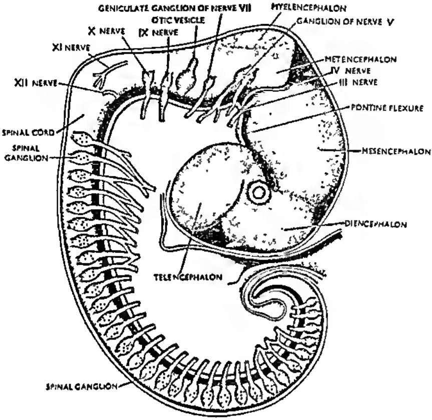

Fig. 202. Diagrammatic representation to show the developing nervous system.

Cerebral Commissures. It may be remembered that, for sometime, both the ventral and dorsal ends of the neural tube remain open and the openings are called anterior and posterior nueropore respectively. Both the neuropores are closed at a later date, and the closing membrane of the anterior neuropore is known as the *lamina terminalis.* Opposite the ventral part of the lamina terminalis a bundle of fibres known as the *anterior commissure* connects the olfactory tract and hippocampus of one side with that of the opposite side. Dorsal to the anterior commissure another bundle of fibres known as the *hippocampal commissure* connects the hippocampal gyrus of one side with that of the other side through the fornix on the lamina terminalis. The *corpus callosum,* the largest band of commissural fibres, connects one cerebral hemisphere with the other and crosses in the lamina terminalis dorsal to the hippocampal commissure. At first it forms a small bundle of fibres but soon it develops rapidly both forwards and backwards to form a large bundle to which other fibres are also added. With the rapid growth and expansion of the corpus callosum the paraterminal body together with the rest of the lamina terminalis becomes stretched and thinned out to form the *septum lucidum.*

Diencephalon. During the earlier part of sixth week of fœtal life the diencephalon, which constitutes the dorsal part of the forebrain, consists of a thin roof-plate, a floor plate, two lateral walls and a cavity within, which later on, forms the third ventricle. At this stage if a sagittal section is made, each lateral plate shows

a groove which runs obliquely from the floor of the mid-brain to the optic recess and is known as *sulcus hypothalamicus*. The sulcus hypothalamicus subdivides each lateral plate into *upper thalamic region* and *lower hypothalamic region*. The cells of the ependymal zone of the thalamic region proliferate rapidly to form a projecting mass, the *thalamus*, towards the cavity of the third ventricle. Below the hypothalamic sulcus the hypothalamus proper together with the infundibulum, pituitary body, tuber cinerium, mamillary bodies and the posterior perforated substance, can be seen to develop. Just below the roof-plate and above the thalamus the structures of the epithalamus, namely, the pineal body, trigonum habenulæ and the striæ habenulæ are developed. The roof-plate itself develops into choroid plexus of the third ventricle during the second month of fœtal life.

MESENCEPHALON

After the appearance of the primary brain flexures the mesencelphalon or the mid-brain forms the most conspicuous feature of the neural tube. But subsequently it fails to show the same rate of growth as the fore- and hind-brain and consequently it remains as a narrow band of neural tube interposed between the hind- and the fore-brain. Its walls, namely, floor-plate, roof-plate and lateral walls, gain considerably in thickness and as a result the cavity of the mid-brain is reduced to a narrow passage, the *aqueduct of the mid-brain*. Cells from both the basal and alar laminæ are represented into it and those of the basal lamina migrate into its floor-plate and are arranged into small clusters to form the nuclei of the third and the fourth cranial nerves. The red nucleus, the cells of which are believed to be derived from the alar lamina, is also located in the floor-plate. The cells of the alar lamina migrate to the roof-plate to form the quadrigeminal bodies.

RHOMBENCEPHALON OR THE HIND-BRAIN

The rhombencephalon or the hind-brain consists of pons, cerebellum and the medulla oblongata and develops from the hind-brain vesicle, and its cavity becomes modified to form the fourth ventricle. The hind-brain vesicle can be divisible into cranial and caudal parts known as *metencephalon* and *myelencephalon* respectively. From the metencephalon the pons and the cerebellum develop whereas the myelencephalon gives rise to the development of the medulla oblongata. The cavity of the hind-brain vesicle, which later on forms the fourth ventricle, is continuous with the central canal of the spinal cord caudally and with the aqueduct of the mid-brain cranially. It consists of a roof-plate, a floor-plate and two lateral plates, one on each side. As in the spinal cord, the sulcus limitans, which appears on either side on each lateral plate, subdivides the neural tube into ventral or basal lamina and dorsal or alar lamina and the cells in these laminæ are arranged into inner or ependymal, outer or marginal and intermediate or mantle zones.

Myelencephalon. With the appearance of the pontine flexure the roof-plate of both myelencephalon and metencephalon becomes very much stretched and thinned out to form the superior and inferior medullary vela. As a result of stretching of the roof-plate each lateral plate becomes displaced to the floor and consequently both the basal and the alar laminæ come to lie in the floor together with the sulcus limitans in between them. The floor-plate at the same time, being invaded by the decussating fibres from the opposite side, is converted into the median raphe on either side of which there lies the basal lamina. The cells of the basal and alar laminæ multiply rapidly and re-arrange themselves in small clusters to form different nerve nuclei as described below:

The nerve nuclei derived from the basal lamina. The cells of the mantle zone of the basal lamina re-arrange themselves into three interrupted columns to form the motor nuclei of the following nerves:

(*a*) The most medial column of cells forms the *somatic motor group* and forms the

nucleus of the hypoglossal nerve and supplies the muscles derived from the body somites (occipital somite) through the hypoglossal nerve.

(*b*) Lateral to the somatic motor group the column of cells forms the *branchial* or *special visceral motor group* from which the nerve nuclei of the V, VII, IX, X, and XI cranial nerves (including the nucleus ambiguus) are derived and fibres from these supply the striped musculature of the visceral arches.

(*c*) Lateral to the branchial motor group the column of cells form the *splanchnic* or *visceral motor group* from which the visceral motor nuclei of the IX, X, XI and the VII (salivary nuclei) cranial nerves are derived and the fibres from these are destined to supply the musculature of the heart, the plain muscles of the lungs and alimentary canal, and the secreto-motor fibres for the salivary and the lacrimal glands.

The nerve nuclei derived from the alar lamina. The cells of the alar lamina arrange themselves in two columns which form the sensory nuclei as follows.

(*a*) The medial column of cells known as the *visceral* or *splanchnic sensory column* forms the sensory nucleus of the VII, IX, X and the XI cranial nerves and they receive afferent impulses from the respective territory of the individual nerve.

(*b*) The more lateral column is known as the *somatic sensory column* which forms the sensory nucleus of the V nerve and the nuclei of the VIII nerve. The gracile and cuneate nuclei which form the cell-station for the proprioceptive impulses also lie in this line.

Metencephalon. From the floor-plate of the metencephalon the pons is derived while from its roof-plate the cerebellum and the superior medullary velum are derived.

Here too, the cells of the mantle zone of the basal lamina are arranged into three columns. The most medial column gives rise to the abducent nerve nucleus (somatic motor). The intermediate column of cells form the motors nuclei of the fifth and seventh nerves (branchial motor). The lateral column of cells forms the salivary nucleus of the facial nerve (visceral motor). The cells of the alar lamina form the sensory nuclei of the eighth (cochlear and vestibular divisions) and the fifth nerves. Some of the cells of the alar lamina from both the myelencephalon and metencephalon migrate ventrally to form pontine nuclei, the nuclei of the formatio reticularis and corpus trapezoideum.

At the dorso-lateral border, on each side, the cells of the alar lamina rapidly proliferate to form a mass which projects both ventrally into the fourth ventricle as well as dorso-laterally, and this elevated mass is called the *rhombic lip*. The cells of the rhombic lip further proliferate and the cell mass of each rhombic lip extends medially and finally meet and fuse together to form the *vermis of the cerebellum*. Subsequently the cell-mass extends dorso-laterally to form the *cerebellar hemisphere*. The cells of the mantle zone then migrate to the marginal zone and give rise to the formation of the cerebellar cortex. Some of the cells of the mantle zone do not migrate but they remain *in situ* to form different cell-masses which constitute the buried nuclei of the cerebellum (dentate nuclei, nucleus emboliformis, nucleus fastigii, nucleus globosus).

Some of the cells of the rhombic lip migrate forwards into the pons and medulla oblongata to form the nuclei pontis, nuclei of the corpus trapezoideum and the reticular formations.

SKELETAL SYSTEM

The skeletal system consists of the bones and the cartilages that build up the structural framework of the body. Morphologically the whole skeletal system can be subdivided into *axial* and *appendicular skeleton*. The axial skeleton consists of the bones and cartilages that build up the vertebral column, the skull, the ribs and the sternum. The appendicular skeleton consists of the bones of the shoulder and pelvic girdles together with the limb-bones connected to them.

DEVELOPMENT OF THE AXIAL SKELETON

Development of the vertebræ, ribs and sternum. During the third week of the fœtal life the paraxial mesoderm undergoes segmentation and becomes organised into somites which form the principal manifestation of the segmentation of the embryo. The somites in the head and tail regions of the embryo degenerate while those in the neck and in the body differentiate into a lateral and a medial

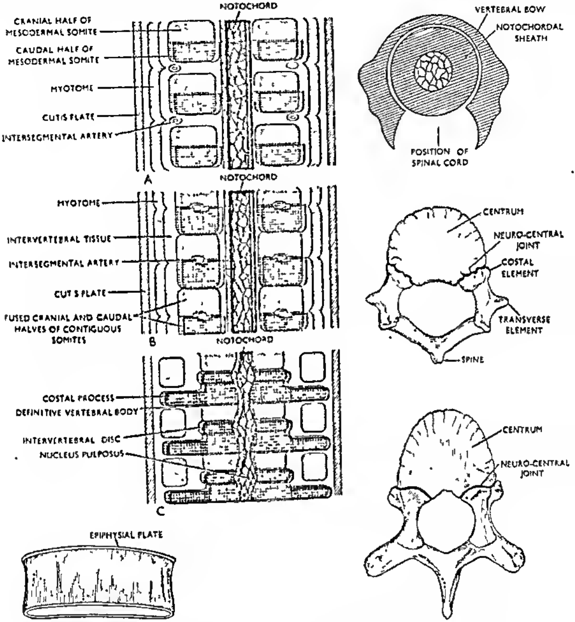

Fig. 203. Diagrams to show the development of vertebra.

portion. The lateral portion is called the *myotome* which gives origin to the skeletal muscles while the medial portion is called the *sclerotome* which gives origin to the connective tissue, cartilage and the bones of the trunk and the neck. The sclerotomic cells from each pair of somites then migrate medially and surround the notochord and forms a sheath around it; they also form a horse-shoe-shaped bow, the *vertebral bow*, the arch of the bow passing in front of the notochord with its sheath. The arch of the vertebral bow ventral to the notochordal sheath is known as the *hypochordal bow.* Dorsally the vertebral bow surrounds the neural tube to form

the *neural arches*. The notochord and its sheath from the sclerotome forms the primordium of the vertebral *centrum*. The hypochordal bow soon disappears except in case of the first cervical vertebra where it forms the anterior arch. The sclerotomic tissue thus separates it from the gut in front and the neutral tube behind. When the sclerotomic tissue has migrated from the somite, the notochord lies within a condensed mass of sclorotomic tissue which shows its original segmented character.

Each mass of sclerotomic tissue that surrounds the notochord, is then differentiated into a caudal condensed portion and a cranial less condensed portion. Later on, the cranial less condensed portion of one block fuses with the caudal more condensed portion of the block above and thus the vertebral centrum is formed. The membranous vertebral centrum formed by the fusion of the two different original segments becomes inter-segmental in position whereas the myotomes and the segmental nerves that supply them maintain the original segmental character in the somites. The sclorotomic tissue forming the neutral arches, gives rise to the development of the transverse processes and the costal elements, all of which grow intersegmentally. The neural arches extend dorsally around the developing spinal cord and subsequently fuse in the middle line to form the primordium of the spinous process. The transverse processes extend laterally only for a short distance and lie in the intermyotomic cleft. With the development and extension of the myotomes into intercostal and lumbar musculature the costal elements grow from the sclerotomic tissue as membranous ribs which later on become chondrified and then ossified. The costal elements are best developed in the thoracic region where they remain separate to form the definitive ribs.

In the ventral aspect of the thoracic region opposite the median plane, later on, the cartilaginous sternal bar forms from the mesenchymal tissue and connects, on each side, the growing ends of the rib cartilages. With the completion of the body wall the sternal bar of each side meets together, first cranially, to form the manubrium sterni, and later on, caudally, to form the body and the xiphoid process of the sternum. Failure of fusion usually results in the formation of the *sternal foramen* in the body of the sternum or a forked xiphoid process in the region of the same.

Development of the skull. The developing brain is surrounded by a mesenchymal condensation which forms the primary protective barrier; later on this mesenchymal condensation at certain places changes into cartilaginous bars (cartilaginous barrier) which are ultimately changed into bone (bony barrier) by process of ossification while at some places ossification starts directly into the mesenchymal tissue without being changed into intermediary cartilaginous stage. This phagic protective mechanism for the delicate brain tissue which is aptly and suitably organised by nature, is the outcome of necessity in the existing condition. It has been seen that the bones at the base of the cranium are preformed in cartilage whereas those at the vault are preformed in membrane; this is because the telencephalon (fore-brain), which grows out of proportion to other parts of the brain, has got to be accommodated and a membranous protection can better adapt to suit the condition; moreover for the future moulding during parturition the membranous basis of ossification becomes a necessity. With the growth, the brain gradually puts in weight and for its support, a more rigid base is a necessity, for which, perhaps, the basal bones (of cranium) are chondrified before ossification; moreover for moulding to take place suitably some resistant support is also necessary and chondrification of the basal bones thus assists moulding indirectly. Besides the formation of the rigid protective barrier around the developing brain, the bones of the jaws are also developed in association with the skull bones. Thus the development of the skull can be discussed under two heads, *neurocranium* which is specially designed to protect the developing brain and the *viscerocranium*, that is, the bones in relation with the skull that develop in association with the visceral arches.

Neurocranium. As already stated the mesenchymal tissue that surrounds the region of the developing brain becomes condensed to form the first protective barrier around it. Subsequently, at some places, the condensed mesenchymal mass becomes chondrified in which, later on, ossification starts, but in other places,

particularly in the region of the vault of the cranium, it remains membranous where ossification starts directly in the membrane.

During the second month of intrauterine life, the mesenchymal tissue caudal to the developing brain shows signs of chondrification to form cartilaginous bars from which the bones of the basal region of the skull are formed. This primitive cartilaginous framework at the basal region of the skull is known as *chondrocranium.* This chondrocranium appears as two cartilaginous bars, one on each side in relation to the cranial end of the notochord; the portion of the chondrocranium that extends ventrally beyond the notochord is known as *prechordal plate* or *prechordal chondrocranium* and that lies on either side of its cranial end is known as *chordal chondrocranium.* The olfactory and visual sense organs develop in association with the prechordal chondrocranium while the auditory sense organ develops in association with the chordal chondrocranium. These plates of cartilages (human chondrocranium) are perforated variously for the passage of the cranial nerves and vessels.

The prechordal chondrocranium. The prechordal chondrocranium lies ventral to cranial end of the notochord and as the latter terminates in the region corresponding to the hypophyseal fossa the prechordal chondrocranium lies ventral to the sella turcica. Ventrally this cartilaginous plate forms the cartilaginous nasal capsule which does not join in the formation of the cranial cavity but it forms the basis of the future nasal chambers. Dorsal to the nasal capsule the prechordal chondrocranium forms a broad perforated plate of cartilage on which primitive olfactory bulbs lie and which gives passage to the olfactory nerves through its openings. This perforated plate forms the future cribriform plate of ethmoid. Dorsal to this perforated plate the prechordal chondrocranium shows lateral extentions which resemble like the lesser wings of the sphenoid and give rise to the formation of the same (lesser wings) and is known as *ala orbitalis.* Each of these expanded plates is perforated on either side of the median plane for the passage of the optic nerve and joins with the central mass of cartilage ventral to the *hypophyseal fossa.* Adjoining the central mass of cartilage on either side is a small bar of cartilage which forms the base of the greater wing of the sphenoid, and this small bar of cartilage joins laterally with a plate of mesodermal condensation, the *ala temporalis* from which the most of the greater wing develops in membrane. Between the ala orbitalis and ala temporalis is the passage (superior orbital fissure) for the transmission of third, fourth, ophthalmic division of the fifth, and the sixth cranial nerves to the orbital cavity. A bar of cartilage extends from the ala orbitalis to the cartilaginous bar forming the base of the greater wing and isolates a portion of the superior orbital fissure to form the foramen rotundum and thus the maxillary nerve, which passes through the foramen rotundum, is separated out from the rest of the structures passing through the superior orbital fissure. The cartilaginous bar which forms the base of the greater wing extends backwards to lie on the lateral side of the carotid sulcus and gives rise to the formation of the future lingula of the sphenoid and is often termed the *sphenotic element.* The central mass of cartilage during the early developmental period is perforated opposite the sella turcica for the passage of the pharyngeal diverticulum which forms the anterior lobe of the pituitary body and the canal through which it passes is known as the *craniopharyngeal canal.* At a later date the craniopharyngeal canal obliterates by extension of ossification both from pre- and post-sphenoid.

Chordal portion of the chondrocranium. The chordal portion of the chondrocranium lies behind the sella turcica and associated with it are the two auditory sense organs, one on each side. Posterolateral to the body of the sphenoid the cartilaginous auditory capsule makes its appearance and between it and the ex-occipital is a gap which forms the jugular foramen for the exit of internal jugular vein and the ninth, tenth and the eleventh cranial nerves. On the cartilaginous auditory capsule the orifice for the seventh and eighth cranial nerves is conspicuous and forms the future internal auditory meatus. The subarcuate fossa on it is also very well marked, although it becomes rudimentary in the adult bone. [Behind the body of the sphenoid is the basioccipital whereas on either side of the foramen magnum is the ex-occipital.

its upper and lower borders and therefore the *superior and inferior vertebral notches are of equal depth.*

THE LAMINAE are longer, narrower and thinner than those of the other regions.

THE SPINOUS PROCESS is very short, *bifid* and ends into two terminal tubercles of unequal size.

THE ARTICULAR PROCESSES form two *articular pillars*, one on each side, which project laterally from the junction of the pedicle and the lamina. On the upper and the lower end of each articular pillar is the superior and the inferior articular facet respectively.

THE TRANSVERSE PROCESS: The most distinguishing feature of the transverse process is the presence of a foramen called the *foramen transversarium*. It consists of an *anterior* and a *posterior root* which are joined together on the lateral side of the foramen transversarium by a curved plate of bone, called the *costo-transverse bar*. Each root ends laterally into a tubercle known as the *anterior* and *posterior tubercle* respectively. The anterior root, anterior tubercle, costo-transverse bar, posterior tubercle and adjoining portion of posterior root of the transverse process are homologous with the rib in the thoracic region whereas the rest of the posterior root is homologous with the true transverse process of the thoracic vertebra.

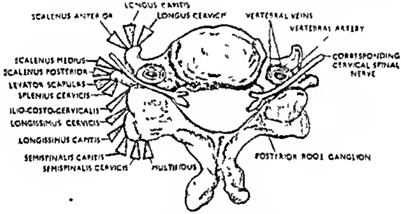

Fig. 208. The muscular attachments to the transverse and articular processes of a cervical vertebra
Note the relations of the vertebral vessels with the spinal nerve.

Particular features. The anterior surface of the body is convex from side to side and its upper and lower borders give attachment to the *anterior longitudinal ligament* and the intervening portion is just covered by the same ligament. On either side of the median plane there is a slight depression which gives attachment to some fibers of the *longus cervicis* (Longus coli) muscle. The posterior surface presents one or two irregular appertures for the passage of the *nutrient artery* and the *basivertebral* veins. Its upper and lower borders give attachment to the *posterior longitudinal ligament*. Its superior surface is concave from side to side and presents an upwardly projecting lip on either side. The anterior border of the upper surface is slightly bevelled. The inferior surface is concave from before backward and slightly convex from side to side, *i.e.*, it is saddle-shaped. Its anterior border projects downwards forming a lip which fits in with the bevelled anterior border of the upper surface of the vertebra below and thus hides the intervertebral disc from the view from the front. Its lateral margin is bevelled so as to fit in with the upwardly projecting lip [illegible] r superior surface

interspinalis, and *semispinalis cervicis.* The articular pillars of the third and the fourth cervical vertebrae present a slight groove on their lateral aspect for the passage of the posterior primary rami of the third and the fourth cervical nerves. The superior articular facets look upwards and backwards and the inferior articular facets look downwards and forwards. The superior articular facets articulate with the inferior articular facets of the vertebra above and the inferior ones articulate with the superior articular facets of the vertebra below forming synovial type of joints. The transverse process is pierced by the foramen transversarium which transmits *the vertebral artery, the vertebral vein* and *a branch from the inferior cervical sympathetic ganglion.* The cervical spinal nerves, as they lie on the transverse process and pass laterally, they pass behind the vertebral artery with its accompanying vein and nerve; the anterior root of the transverse process ends laterally in a tubercle which gives attachment (origin) to *scalenus anterior, longus cervicis* (oblique portion) and *longus capitis* muscles; the anterior root of the transverse process of the sixth cervical vertebra is very prominent and enlarged and lies just behind the common carotid artery which can be compressed against it and hence it is called the *carotid tubercle;* the costo-transverse bar is oblique in direction being directed backwards, downwards and laterally; it is sightly grooved for the passage of the spinal nerves; the costo-transverse bar of the sixth cervical vertebra is less oblique and is conspicuously wide; the posterior root ends laterally in a tubercle which lies at a lower level than the anterior tubercle except in case of the sixth cervical vertebra where the two tubercles lie almost in the same level. The posterior tubercle gives attachment to *scalenus medius, scalenus posterior, levator scapulæ, splenius cervicis, longissimus cervicis* and *costo-cervicalis* (iliocostalis cervicis).

First cervical vertebra. Special features. The first cervical vertebra is called the *Atlas* because it supports the globe of the head. It is ring-like and *has no body* and *spine.* It consists of two bulky lateral masses which are joined together in front, by the *anterior arch,* and behind, by the *posterior arch.* During the process of development the centrum of the first cervical vertebra becomes fused with the centrum of the second cervical vertebra where it forms the dens (odontoid process.)

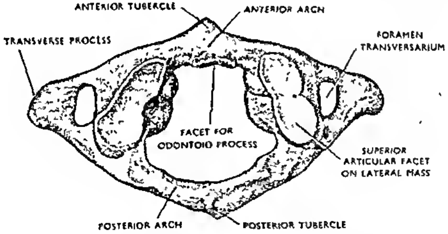

Fig. 209. The atlas or the first cervical vertebra. Viewed from above.

The *anterior arch* is convex anteriorly and presents a tubercle, the *anterior tubercle* opposite to the median plane; its posterior surface is concave and presents a circular facet for articulation with the dens (odontoid process) of the axis. The *posterior arch* presents a shallow groove on its upper surface immediately behind the lateral mass. Posteriorly it presents a small tubercle, the *posterior tubercle,* representing the *rudimentary spinous process.* The lateral mass is placed obliquely so that its long axis is directed forwards and medially. Superiorly it presents a large concave facet which is constricted opposite to its middle point. Inferiorly it presents one circular or oval facet for articulation with the superior facet of the second cervical vertebra. The

transverse process is usually long and the distance between the tips of the two transverse processes greatly exceeds that of the other cervical vertebrae except the seventh.

Particular features. ANTERIOR ARCH. The anterior tubercle gives attachment to the *anterior longitudinal ligament* by its tip, and by its sides it gives insertion to the *oblique portion* of the *longus cervicis* muscle. Its upper border gives attachment to the *anterior atlanto-occipital membrane*. Its lower border gives attachment to the lateral fibres of the *anterior longitudinal ligament*. Morphologically the anterior arch represents the ossified hypochordal bow.

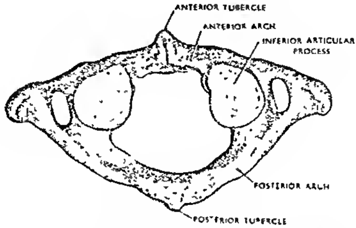

Fig 210 The atlas or the first cervical vertebra Inferior aspect, seen from above and behind

POSTERIOR ARCH. The groove on the posterior arch lodges *the first cervical nerve* and the *vertebral artery* (third part), the latter being placed over the former. This groove sometimes may be converted into a foramen by a bony spicule extending from the lateral mass to the posterior arch. The upper border of the arch medial to the groove gives attachment to the *posterior atlanto-occipital membrane*. Its lower border gives attachment to the highest pair of the *ligamenta flava*; the posterior tubercle gives attachment to the *ligamentum nuchae*, and on either side, it gives origin to *rectus capitis posterior minor*. Owing to the absence of the spine, and the posterior tubercle being smaller, free nodding movement of the head is possible.

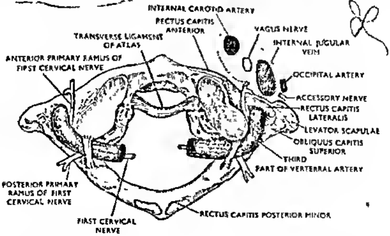

Fig 211. The top view of the first cervical vertebra showing neurovascular relations and muscular attachments.

Note the position of the transverse ligament of the atlas and the ligamentous band that stretches between the lateral mass and the posterior arch of the atlas.

Lateral Mass. The superior articular facet is concave and is directed upwards and medially; it articulates with the condyle of the occipital bone. The facet is so adapted that nodding movement in the atlanto-occipital joint is absolutely free; opposite to its middle the facet presents a constriction and sometimes it is completely divided into two facets. Its margin gives attachment to the *articular capsule* of the *atlanto-occipital joint.* The inferior articular facets are circular or oval, and are directed downwards and medially and slightly backwards; they articulate with the superior articular facets of the second cervical vertebra; its margin gives attachment to the *articular capsule* of the *atlanto-axial joint.* On the medial aspect of the lateral mass there is a small rounded tubercle which gives attachment to *transverse ligament of the atlas*. This ligament divides the ring of the atlas into a smaller *anterior part* and a larger *posterior part;* the anterior part transmits the dens (odontoid process) of the axis whereas the larger posterior part transmits the spinal medulla (spinal cord) with its membranes. The transverse ligament of the atlas supports the dens and helps to keep it in position. The anterior part of the lateral mass gives origin to a few fibres of the *rectus capitis anterior muscle.* There is a small tubercle on the upper part of the anterior aspect of the lateral mass which represents the anterior tubercle of the transverse process of a typical cervical vertebra.

The *transverse process* ends laterally into a single tubercle which is directed downwards and laterally; there is no costo-transverse bar and there is no separate existence of the anterior and the posterior tubercles. The down-turned end of the transverse process is homologous with the posterior tubercle of the transverse process of a typical cervical vertebra and can be felt through the skin at a point midway between the tip of the mastoid process of the temporal bone and the angle of the mandible. The following muscles are attached to this process.

(1) *Rectus capitis lateralis* arising from the anterior part of its upper surface.
(2) *Obliquus capitis superior* arising from the posterior part of its upper surface.
(3) *Levator scapulae* arising from the tip and the adjoining part of the superior surface.
(4) *Splenius cervicis* inserted into its inferior surface.

The anterior surface of the transverse process is in relation to the anterior primary ramus of the first cervical nerve, internal jugular vein, occipital artery and the accessory nerve; the occipital artery and the accessory nerve cross the internal jugular vein in this situation (see fig. 211). The transverse process of the atlas represents the posterior root, costo-transverse bar and posterior tubercle of a typical cervical vertebra.

Axis or the second cervical vertebra. Special features. The most characteristic feature of the second cervical vertebra is the presence of a tooth-like process, the *dens (odontoid process)*, which projects upwards from the superior surface of the body. The dens (odontoid process) acts as a pivot around which the atlas with the skull rotates. It presents a *base* which is attached to the superior surface of the body, and an *apex*, which projects upwards and ends in a conical extremity. On its anterior surface there is a small oval facet for articulation with the similar facet on the back of the anterior arch of the atlas. Posteriorly it presents a shallow transverse groove for the transverse ligament of the atlas.

On each side of the dens (odontoid process) there is a large oval facet on the upper surface of the body which articulates with the inferior facet of the lateral mass of the atlas. The *lamina* of the axis is very thick and strong. The *spinous process* is thick, substantial and is hollowed out inferiorly. The *transverse process* is short and ends into a single tuberculated extremity and does not differentiate into anterior and posterior tubercles; it represents the posterior tubercle of the transverse process of a typical cervical vertebra. The *pedicles* are too short and the *superior vertebral notches* are almost absent while the *inferior vertebral notches* are of considerable depth.

Particular features. The *dens* is conical in shape and measures about half an inch in length. It represents the body of the atlas which has been detatched to get fused with the body of the axis. Posteriorly the shallow transverse groove is caused by the transverse ligament of the atlas which keeps it in position.

A bursa is usually interposed between this part of the process and the transverse ligament of the atlas. Its pointed apex gives attachment to the *apical ligament* and its sides to *alar ligament*. Morphologically the apical ligament represents the fibrous remains of the notochord. The superior surface of the body is obscured by the presence of the dens and the superior articular facets. The inferior surface of the body is concave from before backwards and also from side to side. The anterior margin of the inferior surface forms a projecting lip, a peculiar feature of the axis.

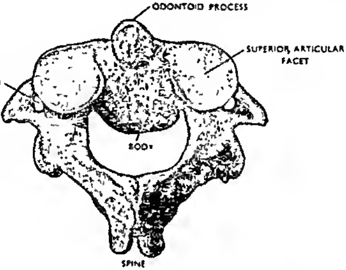

Fig 212. The axis or the second cervical vertebra Posterosuperior view.

The anterior surface of the body presents a ridge in the median plane which is absent in all other cervical vertebrae and gives attachment to *anterior longitudinal ligament*. On either side of the ridge is a depression which gives insertion to the vertical fibres of the *longus cervicis* (longus colli) muscle. The lower part of the posterior surface gives attachment to the *posterior longitudinal ligament*, and to the *membrana tectoria* which projects upwards, covers the odontoid process and the apical ligament and then is attached to the occipital bone; it is the direct continuation of the posterior longitudinal ligament. The *pedicles* are very stout and the *inferior vertebral notches* are of considerable depth in comparison with the superior vertebral notches which are very shallow; the laminae, which are very thick, give attachment to *ligamenta flava*. The *spine*, which is very strong, is grooved inferiorly and gives attachment to *ligamentum nuchae*, and to some of the deep muscles of the back namely, *semispinalis cervicis, spinalis cervicis, multifidus* and *inter-spinalis*; its lateral aspect presents a rough impression for the origin of the *inferior oblique muscle* of the head; its posterior

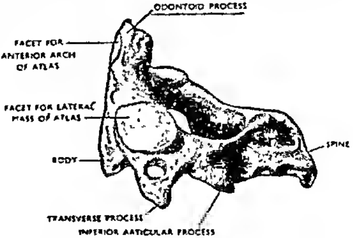

Fig 213. The axis or the second cervical vertebra. Left lateral view.

border gives origin to *rectus capitis posterior major.* The *transverse process* ends in a tubercle which gives origin to *levator scapulae* and *scalenus medius* and more posteriorly gives insertion to *splenius cervicis;* the *intertransversus muscle* is attached both to its upper and lower surfaces. The *foramen transversarium* is directed upwards and laterally, for which the direction of the vertebral artery changes upwards and laterally as it passes upwards to enter into the foramen transversarium of the atlas.

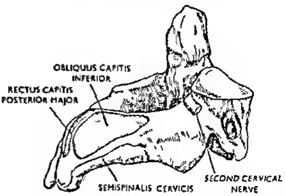

Fig. 214. The right lateral view of the second cervical vertebra showing muscular attachments to the spine.

Sixth cervical vertebra. The sixth cervical vertebra presents the following special features of its identity:—

(1) The *anterior root of the transverse process* is very much prominent and elongated and is known as *carotid tubercle* because the common carotid artery which lies in front of it can be compressed against it when necessary.
(2) The *costo-transverse bar* is conspicuously wide and forms a curved plate of bone.
(3) Both *the anterior and posterior tubercles of the transverse process* lie on the same level. In a typical cervical vertebra the posterior tubercle lies at a lower level than the anterior.

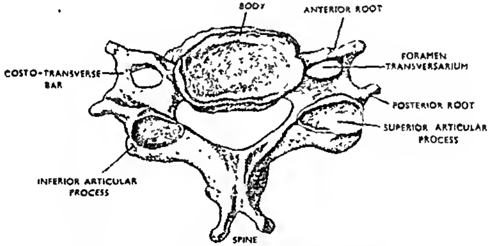

Fig. 215. The sixth cervical vertebra. Posterosuperior view.

Seventh cervical vertebra. Special features. (1) Its *spinous process* is long, horizontal, prominent and ends in a tuberculated extremity. Due to its prominent spinous process, which forms a subcutaneous bony landmark, *it is called the vertebra prominens.* (2) The *transverse processes* are of considerable size and its posterior root is much stouter than its *anterior root which is long and slender.* Sometimes the slender anterior root is sufficiently long and fails to meet the posterior root and forms a separate bone which articulates with the seventh cervical vertebra by a joint constituting the *cervical rib*. The *foramen transversarium* is very small and may be double. The distance between the tips of the two transverse processes is much longer than that of any other cervical vertebra.

Particular features. The tip of the spinous process gives attachment to the

lower end of the *ligamentum nuchae, rhomboideus minor, trapezius, splenius cervicis, serratus posterior superior, semispinalis thoracic, multifidus, interspinalis* and the *spinalis cervicis*. The foramen transversarium transmits the *accessory vertebral vein*. The vertebral artery, vertebral vein and the plexus of sympathetic nerves pass in front of the

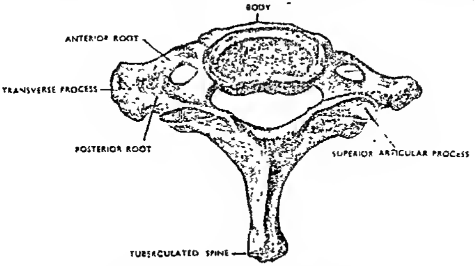

Fig. 216. The seventh cervical vertebra. Posterosuperior view

anterior root of the transverse process. In rare cases the vertebral vessels may pass through this foramen. The posterior tubercle of the transverse process gives attachment to the strong fibrous membrane which covers the cervical dome of of the pleura (*supra-pleural membrane*) and to *scalenus minimus* when it exists. Its undersurface gives attachment to the highest *levatores costarum*.

THE THORACIC VERTEBRAE

The thoracic vertebrae, also known as dorsal vertebrae, are twelve in number and are named numerically from above downwards. The vertebrae, from second to eighth, have common features and are known as *typical thoracic vertebrae*. The *first, ninth, tenth, eleventh* and *twelfth* have special features of their own and are known as peculiar thoracic vertebrae. The group or zonal characteristic of the thoracic vertebrae is the presence of *costal facets on the sides of the body*. Except the eleventh and the twelfth the transverse processes of all the thoracic vertebrae bear the costal facets for articulation with the tubercle of the rib.

A Typical Thoracic Vertebra. **General features.** The body of the typical thoracic vertebra is "*heart*"-shaped being broader antero-posteriorly than from side to side; *on each side of the body there are two articular facets*, the *costal facets, one above and one below*. Both the superior and the inferior facets are half-facets but the superior one is larger than the inferior; it is placed on the upper margin close to the pedicle; the inferior facet is placed on the lower margin close to the inferior vertebral notch.

The pedicles project directly backwards and hence the *vertebral foramen* they enclose is *smaller* and *circular in outline*. The laminae are thick and overlap one another. The spine ends in a *tubercle* and is directed downwards and backwards. The articular surfaces of both the superior and inferior articular processes are flat. The transverse process is *stout* and *club-shaped;* it projects mainly laterally and slightly backwards and presents an articular facet near its extremity for articulation with the tubercle of the numerically corresponding rib.

Particular features. Both the upper and the lower thoracic vertebrae show signs of transition *i.e.*, the bodies of the upper one or two thoracic vertebrae resemble the bodies of the cervical vertebrae and that in the lower thoracic vertebrae resemble

the bodies of the lumbar vertebrae. Both the upper and lower margins of the anterior and posterior surfaces of the body give attachment to *anterior* and *posterior longitudinal ligament* respectively. The margins of the costal facets give attachment to the *capsular ligament* and the *radiate ligament* of the costo-vertebral joint (head of the rib).

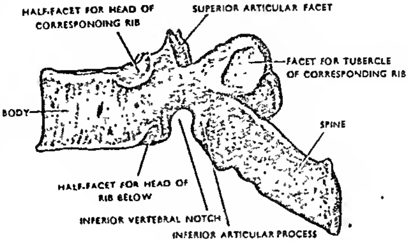

Fig. 217. A typical thoracic vertebra. Left lateral view.

On either side of the median plane the bodies of the first three vertebrae give origin to longus cervicis muscle.

The *pedicles* become gradually thicker from above downwards; the *superior vertebral notches* are almost undiscernible. The *inferior vertebral notches* are of considerable depth because the pedicles are attached to the upper part of the body. The superior border and inferior surface of the laminae give attachment to *ligamenta flava* The *transverse process* gradually diminishes in size from above downwards; the facet on the transverse processes in the upper five or six vertebrae are concave

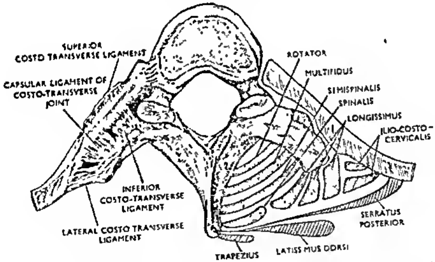

Fig. 218. A schematic diagram to show the disposition of the muscles on the back in relation to the thoracic vertebra.
Note also the costo-vertebral articulation and its ligamentous connections.

and directed forwards and laterally and those on the lower thoracic vertebrae are flat and are directed upwards, forwards and laterally; the lateral end of the transverse process gives attachment to *lateral costo-transverse ligament;* its lower border gives attachment to the *superior costo-transverse ligament* and the *intertransversus muscle;* its anterior surface medial to the costal facet gives attachment to *inferior costo-transverse ligament;* its base gives attachment to *posterior costo-transverse ligament;* its upper border gives attachment to *intertransversus muscle;* its posterior surface gives attachment to the deep muscles of the back; the posterior part of its lateral end gives origin to *levator costae muscle.* The *spine* is oblique in direction in general but from fifth

to eighth dorsal vertebrae it is vertical in direction and overlaps one another in an articulated skeleton. The spine gives attachment to *supraspinous* and *interspinous ligaments* and to a number of muscles, namely, *trapezius, rhomboideus major and minor, serratus posterior superior* and *inferior, latissimus dorsi, semispinalis capitis, multifidus* and *sacrospinalis.*

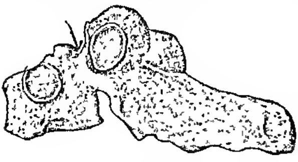

Fig. 219 The first thoracic vertebra. Left lateral view.

First thoracic vertebra. (1) Its *body* resembles like a cervical vertebra and is broader from side to side than from before backwards. (2) The postero-lateral margins of the upper surface of the body are lipped like the cervical vertebrae. (3) The *body presents a single circular costal facet above,* and *a half-facet below.* (4) *Superior vertebral notches* are of considerable depth. (5) The *spinous process* is horizontal in direction. (6) Absence of foramen transversarium distinguishes it sharply from the cervical vertebrae.

Tenth thoracic vertebra. (1) It presents a single, full costal facet at the upper part of the junction of the pedicle and the body (extends both on to the body and the pedicle) which encroaches on to its upper border. (2) There is no costal facet on the lower part of the body. (3) The transverse process bears the costal facet for the tubercle of the tenth rib.

Eleventh thoracic vertebra. (1) There is a *single full costol facet on the upper part of the body* below its upper border which is placed partly on the body and partly on the pedicle. (2) *Transverse process is rudimentary and there is no costol facet on it.* It may be broken into tubercles. (3) *Inferior articular facets look downwards and forwards.* (4) The *spine is triangular in shape and its upper border* is oblique and its lower border is horizontal.

Twelfth thoracic vertebra. (1) There is a *single full costal facet on the body* much below its upper margin which is placed mainly on the pedicle and partly on the body. (2) The *inferior articular facets are convex and are twisted lateralwords.* (3) *Transverse process* is broken into three tubercles superior, lateral and inferior, and there is no costal facet on it. The superior tubercle corresponds to the mamillary process of the lumbar vertebrae, the inferior tubercle corresponds to the accessory process of the lumbar vertebrae and the lateral tubercle represents the true transverse process. (4) The *body* resembles that of the lumbar vertebrae and is broader from side to side than from before backwards. (5) The *spinous process* is triangular in shape and its upper border is oblique in direction while its lower border is almost horizontal.

THE LUMBAR VERTEBRAE

Lumbar vertebrae differ from the thoracic vertebrae in having no costal facets on the body, and from the cervical vertebrae, in having no foramen transversarium in the transverse process.

The lumbar vertebrae from first to the fourth have common characteristics and are known as *typical lumbar vertebrae* while the fifth has special features of its own and is known as a *peculiar lumbar vertebra.*

General features. The *body* of a typical lumbar vertebra is large and broader from side to side than from before backwards. *There is no costal facet on the body.* The *transverse process* is slender and is flattened from before backwards and elongated (spatula-like) and on its postero-inferior aspect there is a tubercle, the *accessory process* which corresponds to the inferior tubercle of the transverse process of the twelfth thoracic vertebra. The transverse process of the third lumbar vertebra is the longest

of all; its length gradually diminishes both above and below it; that of the first lumbar vertebra is the shortest one. The *vertebral foramen* is triangular. The *superior articular processes* are concave and are directed backwards and medially; on the posterior aspect of each process there is a tubercle, the *mamillary process* which corresponds to the superior tubercle of the twelfth thoracic vertebra. The *inferior articular processes* are convex, and are twisted laterally and are closer to each other, and therefore, the distance between the superior articular processes greatly exceeds the distance between the inferior articular processes. The *spinous process* is quadrangular in shape and projects horizontally backwards.

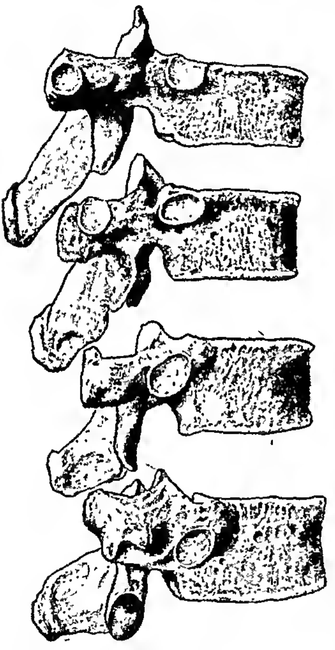

Fig. 220. The ninth, tenth, eleventh and twelfth thoracic vertebrae from above downwards.

Particular features. The *body* is deeper in front than behind; its upper and lower borders, both in front and behind, give attachment to the *anterior* and *posterior longitudinal ligament* respectively. On either side of the anterior longitudinal ligament, the bodies of the first, second and third lumbar vertebrae on the right side, and that of the first and second on the left side, give origin to the right and the left crus of the diaphragm respectively. Posterior to the attachment of the crus, the *psoas major* muscle arises from all the lumbar vertebrae and extends upwards to the twelfth thoracic vertebra. The vertebral foramen of the first lumbar vertebra contains the terminal portion of the spinal cord; the vertebral foramen of the lumbar vertebrae below contains the *cauda equina* and the *spinal meninges*, *i.e.*, *the spinal cord extends up to the lower border of the first lumbar vertebra* and below that only the nerve fibres from the spinal cord which are arranged like the tail of a horse, called *cauda equina*, pass through the canal. The superior vertebral notches are shallower while the inferior ones are of considerable depth. The laminae are short and thick. The spine is quadrangular and its posterior and inferior borders are thick. Its posterior border gives attachment to the *posterior layer of the lumbar fascia*, *supraspinous* and *interspinous ligaments*, the *sacrospinalis*, *multifidus*, *spinalis thoracis* and *interspinalis muscles*. The transverse processes are long and slender; from first to the third lumbar vertebrae they gradually increase and then diminish in size. The transverse process of the third lumbar vertebra is the longest of all; on the anterior aspect of each transverse process, and nearer to its

there is a ridge which gives attachment to the *anterior layer* of the *lumbar fascia.* It divides the surface into medial and lateral areas; the medial area gives

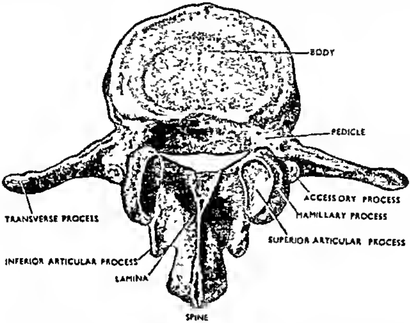

Fig. 221. A typical lumbar vertebra. Seen from above and behind.

origin to the *psoas major muscle* while the lateral area gives origin to the *quadratus lumborum.* The tip of the transverse process gives attachment to the *middle layer of the lumbar fascia;* the tip of the transverse process of the first lumbar vertebra gives attachment to the *medial* and *lateral arcuate ligaments* in addition and that of the fifth to iliolumbar ligament. The posterior surface of the transverse process is covered by the deep muscles of the back and gives origin to *longissimus thoracis;* the corresponding upper and lower borders of the transverse process give attachment to the *intertransversus muscle.* The mamillary process gives attachment to the *multifidus* and the *medial intertransversus muscles.* The accessory process also gives attachment to the medial intertransversus muscle. Developmentally the transverse process is formed by the costal element ($^{2}/_{3}$) and transverse process ($^{1}/_{3}$).

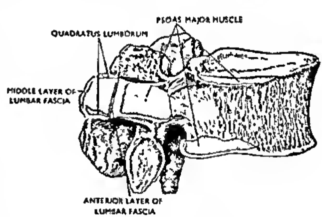

Fig. 222. A mid-lumbar vertebra—lateral view showing attachment of psoas major muscle, the two areas on the transverse process and the attachment of the lumbar fascia on it.

The fifth lumbar vertebra. Special features. (1) The *body* is very large and is deeper in front than behind. (2) The *transverse process* is bulky and stout and conical in shape having a broader base which tapers to a narrow extremity; it arises mainly from the pedicle and encroaches on to the body. (3) The distance between the superior articular processes and that of the inferior articular

processes are almost equal. (4) The *spine* is less substantial and its upper border close to its dorsal extremity is *rounded and downturned.*

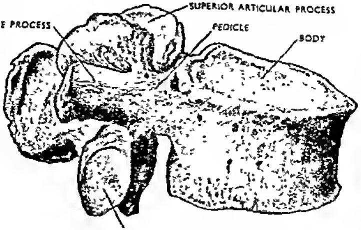

Fig. 223. A typical lumbar vertebra. Right lateral view.

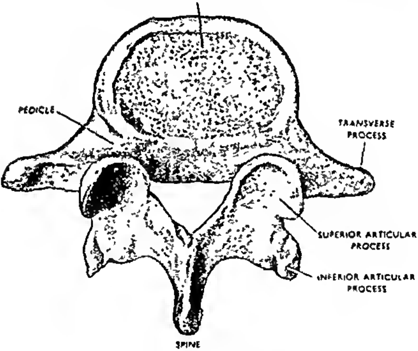

Fig. 224. The fifth lumbar vertebra. Posterosuperior view.

THE SACRUM

General features. The sacrum is a large triangular bone formed by the fusion of the five sacral vertebrae. In an articulated skeleton it is placed obliquely like a wedge in between the two hip bones; owing to its oblique situation it forms an angle with the rest of the vertebral column known as the *sacro-vertebral angle* or the *lumbosacral* angle *which measures about 210 degrees (Frazer). In an articulated pelvis it forms the posterior boundary of the pelvic cavity.

It has a *base,* an *apex,* and three surfaces, *pelvic, dorsal* and *lateral,* a *lateral mass,* and a *sacral canal.*

*The lumbo-sacral angle varies between 128° and 160° with an average of 140° in the male and 137° in the female. Mitchel G. A. G. The lumbo-sacral junction. J. Bone & Joint Surg. 16: 233, 1934.

The base is directed upwards and forwards and consists of an articular part and a non-articular part; the articular part is formed by the upper surface of the body of the first sacral vertebra. It is broader from side to side than from before backwards; the anterior margin of the articular part of the base projects forwards forming a prominent margin known as the *sacral promontory*. The non-articular part of the base projects lateralwards on either side of the articular part as a broad triangular sloping area known as the *ala sacralis*. The ala sacralis forms the upper

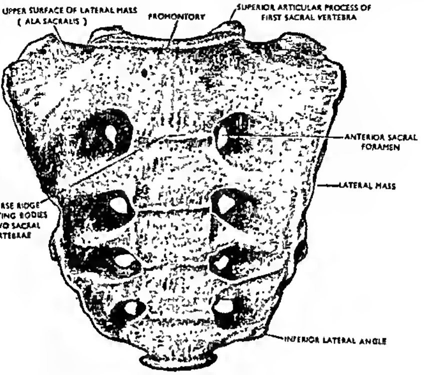

Fig. 225. The sacrum. Pelvic surface

surface of the lateral mass and is formed by the fusion of the transverse and costal elements. The *vertebral foramen* is large and triangular owing to the pedicles being directed backwards and laterally and the laminae are directed downwards, backwards and medially. The *superior articular processes* are concave and are directed backwards and medially; at its lateral part there is a small tubercle which corresponds to the mamillary process of the lumbar vertebra. They articulate with the inferior articular processes of the fifth lumbar vertebra.

The PELVIC SURFACE is concave from above downwards and so from side to side. It is broader above than below. Owing to the oblique position of the sacrum its pelvic surface looks downwards and forwards; opposite to the median plane it presents four transverse ridges on either end of which there is a foramen, the *anterior sacral foramina*. The transverse ridges indicate the line of fusion between the sacral vertebrae; each anterior sacral foramen communicates with the sacral canal through the intervertebral foramen. The bar of bone intervening between two sacral foramina of the same side represents the *costal element;* lateral to the anterior sacral foramina on each side, the costal elements unite with one another to form the *lateral mass*.

The DORSAL SURFACE of the sacrum is convex and looks upwards and backwards; opposite to the median plane it presents a raised crest on which four small tubercles can be distinguished and they represent the spinous processes of the fused sacral vertebrae. Lateral to the median crest the irregular convex area is formed by the fusion of the laminae of the upper four sacral vertebrae; the lamina of the fifth

sacral vertebra fails to meet behind causing an Ω-shaped gap known as the *hiatus*

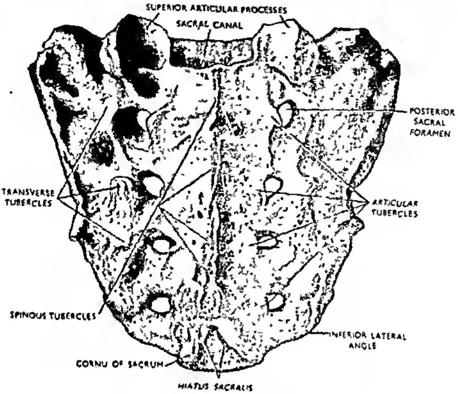

Fig. 226. The sacrum. Dorsal view.

sacralis. Further laterally the posterior surface on each side presents four *posterior sacral foramina* which communicate with the sacral canal through the intervertebral foramen; medial to the posterior sacral foramina there is a row of four small tubercles caused by the fusion of the contiguous articular processes. The inferior articular processes of the fifth sacral vertebra remain free and project downwards as small tubercles, the *sacral cornua,* from the lower end of the lateral margin of the hiatus sacralis. Thus the sacral cornua represent the inferior articular processes of fifth sacral vertebra and articulate with the cornua of the coccyx. The rough area on the lateral side of the posterior sacral foramina is marked by a series of transverse elevations caused by the fusion of the contiguous transverse processes.

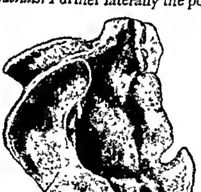

Fig. 227. The sacrum. Left lateral view.

The LATERAL SURFACE is on the lateral aspect of the lateral mass formed by the fusion of the transverse processes and the costal elements; it is broader above and narrow below. At its upper part it presents an ear-shaped articular surface, the *auricular surface,* for articulation with the ilium of the hip bone. The auricular surface resembles an inverted letter L; the horizontal limb of the inverted L is short and is placed on the body of the first sacral vertebra and the vertical limb extends downwards to the lower border of the second or the middle of the third sacral

vertebra. The lower portion of the lateral surface is thin and narrow because this portion of the bone is not required to transmit the body weight; inferiorly it bends forwards and the point at which it bends forms an angle, the *inferior angle*. Below this angle the lateral surface forms a narrow border; posterior to the auricular surface the lateral surface is rough and irregular for ligamentous attachment.

The lower narrow blunt extremity is the *apex of the sacrum;* it is formed by the inferior surface of the body of the fifth sacral vertebra.

The sacral canal is formed by the vertebral foramina of the sacral vertebrae; it is triangular in shape and is bounded in front by the bodies of the sacral vertebrae, and behind and at the sides, by the fused laminae and the spinous processes. The lower part of its posterior wall is deficient because the laminae of the fifth sacral vertebra fail to meet behind and the Ω-shaped gap on its posterior wall is called the *hiatus sacralis*.

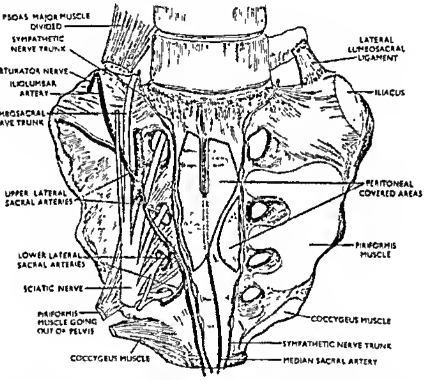

Fig. 228. The pelvic surface of the sacrum showing its relations.

Particular features. (Pelvic surface)—The anterior surface of the lateral mass, opposite to the second, third and the fourth sacral vertebrae, and the bars of bone separating anterior sacral foramina from one another give origin to the *piriformis muscle*. The *pelvic mesocolon* is attached obliquely from the left side of the first sacral vertebra to the right side of the upper part of the third sacral vertebra. Besides the attachment of the above structures, the anterior or pelvic surface of the sacrum bear the following relations.

The anterior sacral foramina transmit the *anterior primary rami of the corresponding sacral nerve* and *a branch from the lateral sacral artery;* the first, second and the third sacral nerves, as they come out of the foramina, lie on the piriformis muscle; medial to the anterior sacral foramina the *sympathetic trunk*, one on each side, descends downwards; lateral to the upper two anterior sacral foramina the *lateral sacral artery* comes into relation with the bone; the artery then descends to the medial side of the lower two anterior sacral foramina and lies on the lateral side of the lower part of the sympathetic trunk. Opposite to the median plane the *median*

sacral artery comes in intimate relation with the bone. Opposite to the bodies of the 1st, 2nd and part of the 3rd sacral vertebrae the pelvic surface is covered by the *parietal peritoneum.* Below this level it is not covered by peritoneum; the *rectum* lies upon the third, the fourth and the fifth sacral vertebrae and the *right* and *left branches* of the *superior rectal artery,* which divides opposite to the third sacral vertebra, intervene between the rectum and the bone.

The dorsal surface of the sacrum is very rough and irregular for muscular and ligamentous attachments; the erector spinae (*sacrospinalis muscle*) is attached both to the spinous and transverse tubercles and forms an U-shaped origin from this surface. The intervening area between the spinous and the transverse tubercles gives origin to the *multifidus muscle,* and is hidden by the sacrospinalis muscle; the posterior sacral foramina transmit the *posterior primary rami of the corresponding sacral nerves* which come out by piercing the sacrospinalis and the multifidus muscles.

The lateral mass of the sacrum is formed by the fusion of the costal elements and the transverse processes of the sacral vertebrae; about 2/3 of it is formed by the costal element and 1/3 by transverse processes. The upper surface of the lateral mass is slightly concave and it is smooth medially and rough laterally; the rough area gives attachment to the *lumbo-sacral ligament* and to the *anterior ligament* of the *sacro-iliac joint.* The upper surface of the lateral mass is covered by the psoas major muscle under cover of which, from medial to lateral side, the *sympathetic nerve trunk,* the *lumbo-sacral nerve trunk,* the *iliolumbar artery* and the *obturator nerve* are related to this area.

The anterior and posterior borders of the first sacral vertebra give attachment to the *anterior* and *posterior longitudinal ligaments* respectively; the lamina of the first sacral vertebra gives attachment to the *lowest ligamentum flavum.*

The auricular surface articulates with the similar surface on the ilium of the hip

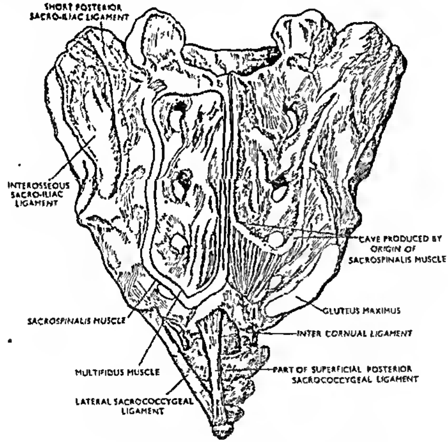

Fig. 229. The dorsal view of the sacrum and coccyx showing muscular and ligamentous attachments.

bone; the rough area behind the auricular surface gives attachment to *strong posterior sacro-iliac ligament.* The lower part of the lateral surface gives attachment to the *coccygeus* in front and *gluteus maximus* behind and in between these two muscles it gives attachment to the *sacrospinous* and *sacrotuberous ligaments,* the sacrospinous ligament being in front and the sacrotuberous ligament behind. The inferior angle gives attachment to *lateral sacro-coccygeal ligament.*

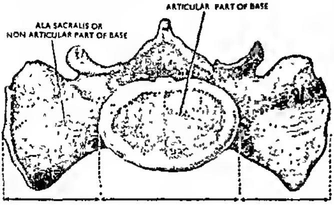

Fig 230 The base of the male sacrum. Seen from above and the front.

Note the relative size of the articular and the non-articular parts of the base.

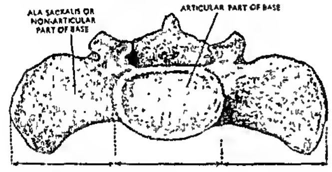

Fig. 231. The base of the female sacrum. Seen from above and the front.

Note the relative size of the articular and the non-articular parts of the base.

The vertebral canal is triangular in form and contains the *cauda equina, filum terminale* and the *spinal meninges.* Opposite to the second sacral vertebra the sub-arachnoid and the subdural spaces end (Fig. 236) and the lower sacral nerves come out by piercing through the spaces. The hiatus sacralis transmits the *fifth pair of the sacral nerves,* the *coccygeal nerves* and the *filum terminale;* in the recent state the hiatus sacralis is closed by *superficial posterior sacro-coccygeal ligament* which is attached to the margins of the hiatus; the *deep posterior sacro-coccygeal ligament* is attached to the floor of the sacral hiatus.

Distinguishing features of the male and the female sacrum—

	Male	Female
Relative size of the articular and non-articular parts of the base	The transverse diameter of the sup. surface of the body of the 1st sacral vertebra is longer than the ala of any side.	The transverse diameter of ala of any side is longer than the transverse diameter of the sup. surface of the body of the 1st sacral vertebra (articular part of base).
Curvature ..	The curvature is gradual from above downwards.	The lower part of the pelvic surface abruptly curves forwards.
Measurements .	Its length always greatly exceeds its breadth opposite to its widest part.	Its length and breadth are almost equal.
Auricular Surface ..	The auricular surface extends up to the upper half of the third sacral vertebra.	The auricular articular surface extends up to the second sacral vertebra.
*Sacral index ..	Lower	Higher
Weight ..	Heavier	Lighter
Muscular impression ..	More marked	Less marked

* **Sacral Index.** It is the ratio between the length and breadth of the sacrum and is expressed by

THE COCCYX

General features. The coccyx is a triangular piece of bone consisting of four small *coccygeal vertebrae*. Sometimes the number of the coccygeal vertebrae may be reduced to three or it may be increased to five. In the adult, usually all the four coccygeal vertebrae unite to form a single piece of bone, but sometimes the first coccygeal vertebra exists as a separate piece. Maintaining the sacral curve it is directed downwards and forwards from the lower end of the sacrum and consequently its anterior surface looks upwards and forwards while its posterior surface looks downwards and backwards.

It has a *base*, an *apex* and *anterior* or *pelvic*, and *posterior* or *dorsal surfaces*. The base is formed by the upper surface of the body of the first coccygeal vertebra. It presents an oval articular surface for articulation with the apex of the sacrum. From the

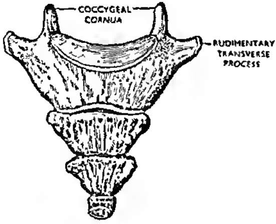

Fig. 232. The coccyx. Anterior aspect.

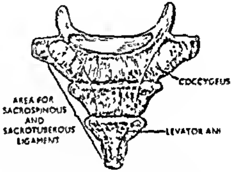

Fig. 233. The anterior aspect of the coccyx showing its muscular attachments.

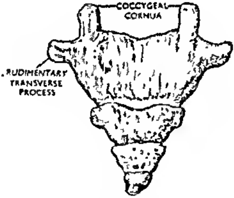

Fig. 234. The coccyx. Posterior aspect.

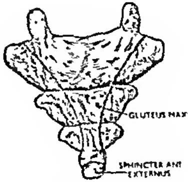

Fig. 235. The dorsal aspect of the coccyx showing its muscular attachments.

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the formula, $\frac{Breadth \times 100}{Length}$. In the females the sacral index is higher than that in the males. In the Britishers the average sacral index in the female is 116 whereas in male it is 112. The sacral index also varies amongst different races and thus it helps as a useful guide in racial differentiation. In cases where the sacral index is above 100 the sacra are *platyhieric* as in Europeans, Negroes and Ploynesians; the sacra in which the sacral index is below 100 are *dolichohieric* as in the Andamanese, Bushmen and Australians.

posterolateral part of the base two bony processes, one on each side, project upwards called the *coccygeal cornua* which represent the pedicle and superior articular processes of a typical vertebra. They articulate with the cornua of the sacrum. *The rudimentary transverse process*, a small bony process, which is gently curved forward, projects laterally from either side of the upper part of the first coccygeal vertebra.

The *apex* is formed by the last segment of the coccyx and it ends into a blunt extremity. The bodies of the second, the third and the fourth coccygeal vertebrae diminish successively in size and they resemble mere nodules of bone without any distinguishing features. The body of the second coccygeal vertebra may present rudimentary transverse processes and the pedicles.

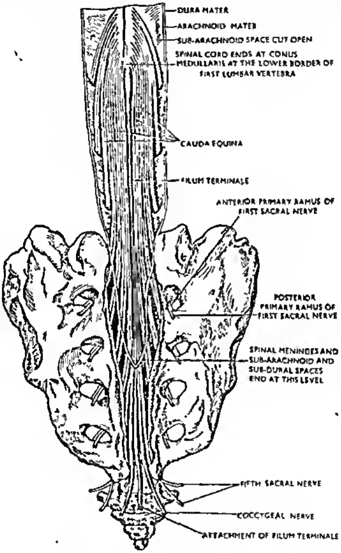


Fig. 236. The dorsal aspect of the sacrum and coccyx with opened up sacral canal.

Note the arrangement of the cauda equina within the sacral canal and the extent of the sub-arachnoid space. Also note the termination of the filum terminale on the coccyx.

Particular features. The base articulates with the apex of the sacrum; the ...ior surface of the first and sometimes the second coccygeal vertebra gives attach-

ment to *anterior sacro-coccygeal ligament.* The coccygeal cornua articulate with the sacral cornua and give attachment to the *intercornual ligament.* The gap between the intercornual articulation and the posterior aspect of the fifth sacral vertebra represents the intervertebral foramen between the fifth sacral and the first coccygeal vertebrae and gives exit to the fifth sacral nerve from the sacral canal. The rudimentary transverse process of the first coccygeal vertebra extends to the *inferior* angle of the sacrum and is connected with it by the *lateral sacro-coccygeal ligament.* The posterior primary ramus of the fifth sacral nerve descends behind the rudimentary transverse process of the first coccygeal vertebra whereas the anterior primary ramus of the same and the coccygeal nerve descend in front of it to gain the anterior aspect of the coccyx. The lateral border of the coccyx gives attachment to sacro-tuberous and sacrospinous ligament. The anterior surface of the body, on each side, extending up to the anterior aspect of the transverse process gives insertion to *coccygeus muscle;* the *levator ani* muscle is inserted in the last two segments of the anterior surface of the coccyx. The dorsal surface on each side gives origin to the *gluteus maximus muscle* and opposite to the tip to the *sphincter ani externus muscle.* Opposite to the median plane, the dorsal surface of the first coccygeal vertebra gives attachment to the *deep* and *superficial posterior sacro-coccygeal ligaments.* The superficial posterior sacro-coccygeal ligament extends from the margin of the hiatus sacralis and sometimes closes the hiatus by its attachment and thus completes the posterior wall of the sacral canal opposite to hiatus sacralis. The *filum terminale* descends downwards in between the superficial and deep posterior sacro-coccygeal ligaments and is attached to the back of the first coccygeal vertebra. The anterior surface of the coccyx is in relation to the rectum, ganglion impar, anastomosis between the median sacral and the inferior lateral sacral arteries, and the coccygeal body.

VERTEBRAL COLUMN AS A WHOLE

When the different vertebrae articulate with one another by the intervention of the intervertebral fibro-cartilaginous discs they form a pillar which supports the head and forms the central axis of the trunk.

If we look to the vertebral column in an articulated skeleton, we can see that the vertebrae articulate with one another in an orderly form. The sacrum, formed by the fusion of the 5 sacral vertebrae, forms a mass of bone, with which the coccyx, formed by the four coccygeal vertebrae, is joined at its apex to form the *sacro-coccygeal mass.* On the top of the sacro-coccygeal mass the remaining vertebrae are placed one above the other with the intervention of a fibrocartilaginous disc (represented by a pad in the articulated skeleton) between them in an orderly form so as to complete the formation of the vertebral column. Tracing from above downwards the column can be divided into four regions, namely, *cervical, thoracic, lumbar* and *sacro-coccygeal.* The cervical region consists of the 7 cervical vertebrae, the thoracic region of 12 thoracic vertebrae, the lumbar region of 5 lumbar vertebrae whereas the sacro-coccygeal region consists of 5 fused sacral and 4 coccygeal vertebrae.

Measurements. In the adult male, the average length of the vertebral column is about 28 inches, and in the adult female, it is about 24 inches. About $\frac{1}{4}$ of the total length is contributed by the intervening fibro-cartilaginous discs. Regionally, in the adult male, the cervical region measures about 5 inches, thoracic region about 11 inches, lumbar region about 7 inches and the sacro-coccygeal region about 5 inches.

We have already learnt about the features of regional vertebrae and now, if we look to them together, as in the articulated vertebral column, we can easily understand about the sound mechanism in the art of construction of the vertebral column. In order to have a better understanding, parts that build up an individual vertebra have been discussed together under separate heads.

Bodies. If we look into the bodies from above downwards it is found that they increase gradually in width from second cervical to the first thoracic vertebra, then the width slightly diminishes up to fourth thoracic vertebra; from fifth

vertebra downwards the width again gradually increases till we reach the first sacral vertebra (base of the sacrum) where it is maximum; below this level the width rapidly diminishes.

The gradual increase in size of the vertebral bodies from above down to the first sacral vertebra is due to the fact that they are to support more and more weight from above downwards; below the first sacral vertebra the bodies rapidly diminish in size because the weight being transmitted down the thighs they are no longer to support the weight.

Transverse processes. Except in the first and seventh, the transverse processes of the cervical vertebrae are usually smaller. The distance between the median plane and the tip of the transverse process of the first cervical vertebra greatly exceeds that of the succeeding vertebrae except that of the seventh where it is greater and is almost equal to that of the first thoracic vertebra. This distance gradually diminishes from second to the twelfth thoracic vertebra where the transverse process is very short and rudimentary being often represented by small tubercles. In the lumbar region the transverse processes are longer than those of the thoracic region and that of the third lumbar vertebra is the longest of all.

Spinous processes. The spinous processes occupy exactly the median plane dorsally. The first cervical vertebra has no spinous process and it is represented by a tubercle. The succeeding spinous processes down to the sixth cervical gradually increase in size and they are bifid and are directed downwards and backwards. The spinous process of the seventh cervical vertebra is directed horizontally backwards and ends in a tuberculated extremity. The spinous process of the first thoracic vertebra is almost similarly disposed but it is smaller than that of the seventh cervical. Because of the large size, tuberculated extremity and horizontal disposition in contrast to oblique spines of the adjacent cervical and thoracic vertebrae the seventh cervical spine stands out prominently as an important landmark which helps in counting the vertebrae. The thoracic spines are oblique in direction being directed backwards and downwards and they end in a tuberculated extremity. This obliquity reaches its maximum in the 9th thoracic vertebra where the spinous process is almost directed vertically downwards. From the tenth thoracic vertebra the obliquity diminishes rapidly and in the lumbar region the spinous processes are again directed horizontally backwards.

The Laminae. In the cervical region the laminae are thinner and they just overlap each other except the first cervical. There is usually some interval between the laminae of the first and the second cervical vertebrae. In the thoracic region the laminae are thicker and stronger and they overlap each other in such a way as if one is a splint for the other. In the lumbar region the laminae do not overlap and normally some interval always exists between two laminae. For the above reasons the mobility of the thoracic region is limited and is very much less than that of the cervical and lumbar regions.

Articular processes. The articular processes differ in details regionally as well as individually in some vertebrae which have already been described. Now if we look into the plane of articulation we find that it is vertical in general except in the cervical region where the plane of articulation is more transverse than vertical and for this, dislocation without fracture is only possible in the cervical region.

Intervertebral foramina. They are formed between two vertebrae by the vertebral notches and are meant for transmission of the spinal nerves. It is bounded above by the inferior vertebral notch of the vertebra above, below by the superior vertebral notch of the vertebra below; anteriorly by the intervertebral disc and the posterior parts of the bodies of two adjacent vertebrae and posteriorly by superior articular process of the vertebrae below. Their size varies regionally depending on the size of the emerging nerve except in the lumbar region where the size of the nerves increases gradually from above downwards but the invertebral foramina do not proportionately increase and instead they gradually diminish in size

from above downwards. As a result, the larger lower lumbar nerves are to negotiate through comparatively smaller intervertebral foramina and the nerves have very little space around them and consequently these lower lumbar nerves are liable to be compressed easily in case of slight diminution in size of the intervertebral foramina from the effects of injury or inflammatory processes.

Vertebral canal. When different vertebrae articulate with one another to form the vertebral column the vertebral foramina collectively form a continuous canal known as the *vertebral canal.* It begins at the lower part of the foramen magnum through which it is continuous with the cranial cavity and ends below at the hiatus sacralis. It is not a straight canal. It follows the vertebral curvatures and forms a wavy canal. The form of the canal is also not uniform throughout its entire extent. Thus in the cervical region it is wider and is triangular in form; in the thoracic region it is smaller and is circular in outline; in the lumbar region it is again triangular while in the sacral region it becomes flattened out and is cresentic in form on transverse section. The canal is bounded in front by the posterior surface of vertebral bodies and the intervertebral discs; posteriorly it is bounded by the vertebral laminae and the ligaments that connect them; laterally the verebral canal is open on either side through the intervertebral foramina. The vertebral canal contains the spinal cord with its meninges and blood vessels, spinal nerve roots and in the lower part of the canal, the cauda equina and the filum terminale.

INTERVERTEBRAL DISCS. Between the bodies of two adjacent vertebrae is an intervertebral disc which acts as a buffer in absorbing shock and forms the main stay in the prevention of injuries to the vertebral bodies and to the spinal cord. Collectively they contribute about ¼th of the total length of the vertebral column and thus also help in adding length to the vertebral column. Each disc is firmly connected with the sub and superjacent vertebrae at the periphery and is loosely connected at the centre. Thus the intervertebral disc also acts as a firm bond of union between two adjacent vertebrae and it is due to this that very little movement is permitted between two vertebrae but collectively the vertebral column is seen to possess wide range of movement. The discs are thicker in front than behind in the cervical and lumbar regions and are responsible for cervical and lumbar convexity of the vertebral column. In the thoracic region it is thinner.

Structure. The intervertebral disc consists of a central, highly elastic gelatinous mass known as the *nucleus pulposus,* and a peripheral annular fibrous band, *annulus fibrosus,* made up of concentrically arranged fibrous tissue. The annulus fibrosus constitutes the main weight bearing portion of the disc and adds strength and form to it.

Histological appearance: **Nucleus pulposus.** Under ordinary microscope there is very little structure to be seen in the nucleus pulposus. The cells are very few and scattered, and the presence of other structures is overshadowed by the intercellular substances.

Under the electron microscope, in children and young persons, the nucleus pulposus shows the presence of numerous collagen fibres running in all directions. The collagen fibres are surrounded by chondromucoid elements of the nature of chondroitin sulphuric acids. By fermentation, the element of chondroitin sulphuric acid is dissolved out leaving bare the purified collagen fibres which could be *seen through the said microscope.* In elderly persons many of the collagen fibres are seen to be uncovered by the chondromucoid elements indicating structural changes with age.

Annulus fibrosus. It consists of concentrically arranged dense fibres as well as other fibres which run in all the directions. The fibres are usually arranged into bundles. Some of the fibres are seen to extend from one cartilaginous plate to the other while some others are found to cross from one vertebra to the other. The fibres are surrounded by chondromucoid material but it is nuch less in amount compared to that in the nucleus pulposus.

Physiological behaviour. Since the age of fifteen no blood vessels are seen to be present within the discs and consequently they are more sensitive to metabolic disturbances than other connective tissues. In doing the test for permeability to materials by diffusion, it was found that the diffusion rate was slow and that only molecules of certain shape can enter into them.

Biochemical constituents. The chemical components of the nucleus consist of protein, polysaccharides and water. With increasing age the water content is decreased, the protein content is increased whereas the polysaccharides are decreased or they remain constant.

Curvatures of the vertebral column. The vertebral column is not a straight pillar but it presents four curvatures, namely *cervical, thoracic, lumbar* and *sacral*. The thoracic and sacral curvatures are concave anteriorly and they are *primary curvatures*, that is, they are formed with growth and development in foetal life and continue in post-natal life. The cervical and lumbar curvatures are *secondary* or *compensatory curvatures* which appear after birth. Both these curvatures are convex anteriorly. The cervical curvature begins to appear when the child sits up while the lumbar curvature begins to appear when the child walks about. In addition, the column may have slight lateral curvature with convexity to the right in right handed person.

Vertebral landmarks. The vertebral column being the central axis, structures come into direct or indirect relation with it. As the vertebrae are more or less fixed in their position, studies as regards course, extent and position of organs and other structures, are made in relation with the vertebrae and thus they are taken into account as landmarks. Therefore it is a matter of great importance to locate the position of an individual vertebra in the recent state.

How to locate an individual vertebra in the living body. It has already been stated that the spines of the vertebrae occupy exactly the median plane dorsally and that they can be felt through the skin by palpation. When the vertebral column is made to bend forward (flexion) the spines are separated apart to stand out prominently and it becomes easier to palpate and to count them. The upper cervical spines cannot be felt easily because of the thick overlying ligamentum nuchae but the seventh cervical spine by virtue of its length, direction and prominence can easily be felt, for which, it is taken as a guide for counting other vertebrae.

In some cases, particularly in fat subjects, palpation of the vertebral spines may be a matter of great difficulty.

In such cases other bony landmarks are taken into account in conjunction with palpation of the spines. The following horizontal lines joining well defined bony landmarks are also considered in locating the vertebrae.

The horizontal line that joins the medial end of the spines of the scapulae crosses the tip of the spine of the third thoracic vertebra. The line joining the inferior angle of the two scapulae passes across the seventh thoracic spine. The line joining the highest points of the two iliac crests passes across the interval between the third and fourth lumbar spines and that joins the posterior superior iliac spines corresponds to the second sacral spinous process.

SOME IMPORTANT VERTEBRAL LEVELS

It has already been stated that the vertebrae, being fixed in their position, are taken as landmarks in describing the soft structures which may or may not come into direct relation with the vertebrae. As for example, the bifurcation of the trachea; it is far off from the vertebral column but the plane at which it terminates corresponds to the lower border of the fourth thoracic vertebra which is the landmark for the said bifurcation. Moreover, in exposing some viscera or some other structures or in doing diagnostic or therapeutic puncture of some structure it becomes convenient to approach them with the knowledge of their vertebral

levels. In the following few lines some of the important vertebral levels have been discussed:

1st cervical vertebra corresponds to:
(1) End of medulla oblongata.
(2) Commencement of spinal cord.

3rd cervical corresponds to:
Hyoid bone.

4th cervical corresponds to:
(1) Bifurcation of common carotid artery into external and internal carotid arteries.
(2) Upper border of thyroid cartilage.

6th cervical corresponds to:
(1) Cricoid cartilage.
(2) Termination of larynx and pharynx.
(3) Commencement of trachea and oesophagus.
(4) Commencement of second part of vertebral artery.
(5) Position of middle cervical sympathetic ganglion beneath the inferior thyroid artery.
(6) Crosing of superior belly of omohyoid and the front of the common carotid artery.
(7) Crossing of inferior thyroid artery and the common carotid arterv.

7th cervical:
Maximum approach of the thoracic duct to this level from where it turns to the left.

2nd thoracic corresponds to:
The suprasternal notch of the manubrium sterni.

4th thoracic corresponds to:
(1) The sternal angle.
(2) Termination of arch of the aorta into the descending thoracic aorta.
(3) Termination of trachea and the commencement of the bronchi.
(4) Origin of left recurrent laryngeal nerve.
(5) Deep and superficial cardiac plexuses.
(6) Termination of azygos vein into superior vena cava.

8th and 9th thoracic:
(1) Between the two the inferior vena cava pierces the diaphragm.
(2) The 9th T. vertebra corresponds to the xiphisternal articulation.

10th thoracic:
Oesophagus pierces the diaphragm.

12th thoracic:
Aortic opening in the diaphragm through which aorta, azygos vein and thoracic duct pass.

1st lumbar:
(1) Transpyloric plane.
(2) Duodeno-jejunal flexure.
(3) Pancre- (Tail).
(4) Pylorus.
(5) Hilum of the kidney.

2nd lumbar:

(1) The spinal cord ends opposite the upper border of 2nd L. vertebra.
(2) The azygos vein begins.
(3) The thoracic duct begins as a continuation of the cisterna chyli.
(4) Head of the pancreas.

3rd and 4th. lumbar:

The disc between the third and the fourth lumbar vertebrae corresponds to the highest point of the iliac crest.

Abdominal aorta bifurcates into two common iliac arteries.

5th lumbar:

Two common iliac veins unite to form the inferior vena cava.

2nd sacral:

(1) The level corresponds to the line joining the posterior superior iliac spines.
(2) Terminal point of the sub-archnoid and subdural spaces.
(3) Level of the sacroiliac articulation.

3rd sacral:

(1) Corresponds to the line joining the posterior inferior iliac spines.
(2) Pelvic colon ends and the rectum begins.
(3) *Superior rectal artery divides into two branches.*
(4) Right limb of the V-shaped pelvic mesocolon ends.

RELATION OF THE VERTEBRAL SPINE WITH SPINAL SEGMENTS

During early foetal life the spinal cord is as long as the vertebral column but later on due to disproportionate growth between the two, the vertebral column growing more than the spinal cord, the latter is drawn up within the vertebral canal and the cord segments no longer correspond to the vertebral segments. Thus at birth the lower end of the spinal cord corresponds to the upper border of the third lumbar vertebra and in the adult it corresponds to the upper border of the body of the second lumbar vertebra.

In order that proper surgical approach can be made to the spinal segments it is essential that one should know about the relation of the spinal segments with the vertebrae. As for example, suppose, we want to expose the 6th thoracic segment which has been involved in some injury or in some disease, and unless we know that that the 6th thoracic segment lies opposite 4th thoracic spine we cannot make an approach definitely. The following few lines deal with the relation of the spinal segments with the vertebrae.

In the cervical region from first to fourth cervical vertebrae the spinal segment is one higher than the number of the vertebral spine, that is, the second cervical spine corresponds to the third cervical segment, the third cervical spine to fourth cervical segment and the fourth cervical spine corresponds to the fifth cervical segment. The sixth cervical segment lies between fourth and fifth cervical spines and the seventh cervical segment lies between fifth and sixth cervical spines. From sixth cervical spine to the fifth thoracic spine the spinal segment is two higher than the number of the vertebral spine, that is, the sixth cervical spine corresponds to the eighth cervical segment, seventh cervical spine to first thoracic segment, first thoracic spine to third thoracic segment, second thoracic spine to fourth thoracic segment, third thoracic spine to fifth thoracic segment, fourth thoracic spine to sixth thoracic segment and fifth thoracic spine corresponds to seventh thoracic segment while the eighth thoracic segment lies between fifth and sixth thoracic spines. From sixth thoracic down to the tenth thoracic vertebra the spinal segment is three higher than the number of the vertebral spine, that is, the sixth spine corresponds to the ninth thoracic segment, seventh thoracic spine to tenth thoracic segment, eighth thoracic spine to eleventh thoracic segment, ninth thoracic spine to twelfth thoracic segment and the tenth thoracic segment corresponds to first

lumbar segment. The eleventh thoracic spine corresponds to third lumbar segment. The interval between tenth and eleventh thoracic spines corresponds to second lumbar segment, and between eleventh and twelfth thoracic spines there lies the fourth and fifth lumbar and first sacral segments, and between twelfth thoracic spine and the first lumbar spine, all the other segments lie.

Ossification of vertebrae

The vertebrae are preformed in cartilage and all typical vertebrae in their cartilaginous form consist of three portions namely the centrum, and the two vertebral arches, one on each side. The centrum represents the future vertebral body except its posterolateral parts whereas each vertebral arch represents the posterolateral portion of the body and the arch proper from which the vertebral processes develop. Each typical vertebra ossifies from 8 centres, three primary and five secondary.

Primary Centres. Of the three primary centres, one appears in the centrum, and one in each vertebral arch. The primary centre for the arch appears first in the region of the future transverse process and then extends forwards to form the pedicle and the posterolateral portion of the body, backwards to form the lamina and lateralwards to form the transverse process. Judged regionally, the primary

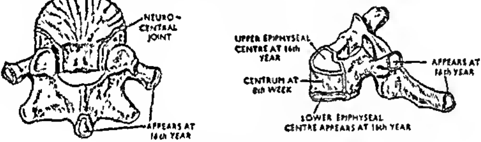


Fig. 237. The ossification of a typical vertebra

centre for the arch is seen to appear during the 7th or 8th week of foetal life, first in the cervical region, and then in the thoracic (10th week), lumbar (15th week) and sacral regions (20th week) successively. The primary centre for the body or the centrum first appears during the 10th week of foetal life in the lower dorsal region and then extends both upwards and downwards. In the cervical and lumbar regions this centre appears almost simultaneously during the 15th week of foetal life but in the sacral region the centre appears during the 20th week.

Each vertebral arch at first joins with the centrum by a plate of cartilage forming a temporary (primary) cartilaginous joint known as the *neurocentral joint*. Each arch unites (becomes osseously continuous) with the body during the third year in the cervical region, during 4th-5th year in the dorsal region, 6th year in the lumbar region and between 6th and 7th years in the sacral region. The two laminae fuse together during the first year in the dorsal and lumbar regions, during second year in the cervical region and between 7 and 10 years in the sacral region.

Secondary centres. All the five secondary centres, two for the body, one for each transverse process and one for the spine, appear after puberty and they fuse with the rest of the bone during 25th year.

The secondary centre for the body appears in the cartilaginous plate, the epiphyseal plate, that covers the upper and lower surfaces of the body. The peripheral margin of this plate is usually ossified, while its central portion remains cartilaginous until extreme old age when it becomes ossified. Secondary centre for the transverse process appears at its cartilaginous tip and that for the spine at its dorsal extremity.

In the cervical region the spinous process has two secondary centres, one for each end of the bifid spine. In the lumbar region there are additional secondary centres for the mamillary processes. The transverse process of the first lumbar and the anterior root (costal element) of the transverse process of the seventh cervical vertebra might have an additional primary centre. In the latter, when such a centre exists, it usually unites with the rest of the process during the fifth year but it sometimes fails to join and may remain separate as the *cervical rib*. In case of first lumbar vertebra the separate centre gives rise to the formation of the *lumbar rib*. In the fifth lumbar vertebra each vertebral arch might have two primary centres, one for the anterior portion and one for the posterior portion and the two centres unite together by an oblique plate of cartilage between the superior and inferior articular processes.

Atlas. The atlas or the first cervical vertebra is preformed in cartilage and is ossified from two primary centres and one secondary centre. The two primary centres, one on each side, appear in the region of the lateral mass during the seventh week of foetal life. The process of ossification then extends backwards from both sides into the posterior arch. The posterior arch at first consists of two segments, right and left, which remain connected with each other posteriorly in the median plane by a plate of cartilage. By the process of extension of the ossifying centres the two segments unite together during the third year. Occasionally one secondary centre of ossification may appear in the intervening cartilage prior to the union of the two segments. The anterior arch together with a small portion of the superior articular facet ossifies from one secondary centre which appears during the first year of life. The anterior arch fuses with the lateral mass between sixth and eighth years while the posterior arch fuses with it between third and fourth years.

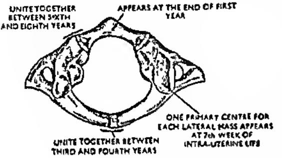


Fig. 238. The ossification of atlas.

Axis. The axis or the second cervical vertebra is preformed in cartilage and is ossified from 5 primary and 2 secondary centres.

The five primary centres are, two for the vertebral arch, one on each side, two for the base of the dens (odontoid process) and one for the body. The centres for the vertebral arch appear during the seventh or eighth week of foetal life, and that for the body appears during the fifth month. The two centres for the dens (odontoid process) make their appearance during the sixth month of foetal life, one on each side of the root of its base. These two centres fuse together inferiorly to form the base of the process before birth and remain connected with the body by an intervening wedge-shaped cartilage. The primary centres of the dens (odontoid process) fail to fuse superiorly so that a cleft remains which is filled-up by a plug of cartilage.

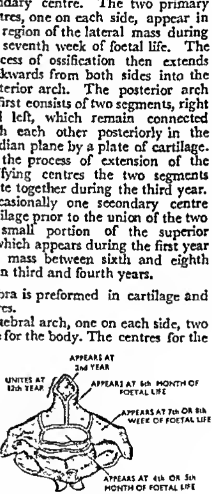


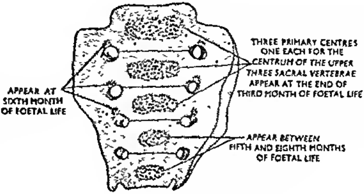
Fig. 239. The ossification of axis.

The two secondary centres are, one for the cartilaginous tip of the dens (odontoid process) and one for the inferior surface of the body. The centre for the cartilaginous tip of the dens (odontoid process)appears at second year and fuses with the main mass before twelfth year. For the lower surface of the body which forms the epiphysis of the centrum, ossification appears during sixteenth year and fuses with the rest of the body at 25th year. The vertebral arch unites with the body between third and

sixth years. The dens (odontoid process) also fuses with the body by the same time but the union is only superficial being limited at its circumferential margin. Its central portion takes a long time to become osseously continuous with the body.

Sacrum. The sacrum is ossified from 35 centres of which 21 are primary and 14 are secondary.

Primary centres. Of 21 primary centres, three are for each sacral vertebra—one for the body and two for the vertebral arches, and 6 for the costal elements of the upper three sacral vetebrae. The primary centres for the body of first, second and the third sacral vertebrae appear at the end of third month, and that for the body of the fourth and fifth sacral vertebrae appear between 5th and 8th months. The primary centres for the costal elements appear in pairs, one on each side, at the upper and outer margins of the upper three anterior sacral foramina between fifth and sixth months of foetal life. The primary centres for the vertebral arches appear during fifth month of foetal life.



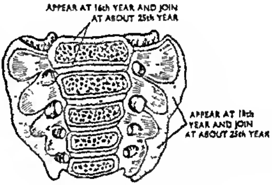


Fig 240. The ossification of sacrum.

Secondary centres. Two secondary centres, one for the upper and one for the lower surface of the body of each sacral vertebra, appear during puberty. Two secondary or epiphyseal centres, one for the auricular articular surface, and one for the narrow edge below it, on each side, begin to appear at about the same time. Different ossifying centres of an individual vertebra fuse together at puberty; at about 18th year fusion between the vertebrae commences from below upwards, and by the 21st year all the vertebrae are fused together except the first sacral vertebra. The latter fuses with the rest of the bone at about 30th year and thus completes the formation of sacrum into a single mass of bone.

Coccyx. At birth the coccyx consists of four cartilaginous nodules and there is no ossifying centre at all. Here the primary centre of ossification appears after birth (deviation from usual law of ossification). Four primary centres, one for each segment, appear between first year and twentieth year from above downwards in the following order. The centre for the first segment appears between first and fourth years, and that for the second, between fifth and tenth years; the centre for the third segment appears between 10th and 15th years, while that for the fourth, appears between 15th and 20th years.

The secondary centres are ten in number of which 8 are for the four segments, 2 for each segment, and 2 for the coccygeal cornua, one on each side. The two secondary centres for each segment, one for its upper and one for its lower surface, appear during puberty (16th year) and fuse with the segment at about 25th year. The lower three segments fuse together at about the same time but the union of the first segment with the rest is further delayed until 30th year. The centre for the coccygeal cornua also appears at the same time (puberty) and fuses with the body at about 25th year. In advanced age the coccyx may be united with the sacrum, particularly in the fem-

ERRORS OF DEVELOPMENT. Errors of development may occur in any of the different elements of one or multiple vertebrae. Thus the neural or vertebral arches or the centrum may be involved and may give rise to different kinds of developmental anomalies.

Errors of development of neural arches. (1) *Spina bifida occulta*—Normally the two neural arches of any individual vertebra grow behind and fuse together in the median plane to form the vertebral laminae and the spine. In the case of errors of development two types of anomalies may be noticed, either the neural arches may fail to develop posteriorly so that considerable portion of the laminae are not formed at all, or they may grow behind sufficiently in two halves to form two laminae, each giving rise to its own spine, but the latter (spines) fail to fuse together, thus the condition of *split spine* may result. Any of the above conditions may be associated with a single vertebra or with multiple vertebrae. When it occurs in a single vertebra the condition is called the *spina bifida* and when in multiple vertebrae, the condition is called *spina bifida occulta*. This condition occurs more commonly in the lumbar region and when present, it may be associated with saccular protrusion of the spinal meninges and nerves, or the cord itself may protrude through the gap and a band of fibrous tissue only intervenes between the skin and the meninges opposite the median plane. When only the meninges come into the protrusion the condition is known as the *meningocele*; when the meninges are associated with a portion of the spinal cord with the nerves the condition is known as *meningo-myelocele* and when considerable portion of the spinal cord together with its meninges and the central canal, which becomes much dilated, come in the protrusion the condition is known as the *syringo-myelocele*.

(2) *Complete rachischisis*. In this condition growth is arrested in the neural groove stage, as a result, the posterior part of the spinal cord, neural arches, muscles and the skin opposite the median plane throughout the whole length of the vertebral column cannot develop. This condition is extremely rare and is not compatible with life birth.

(3) *Incomplete rachischisis or myelocele*. This condition also is not compatible with life. It differs from the above in that here only some portion of the neural groove is arrested in development.

(4) *Sacralization of lumbar vertebra*. In this condition either one or both the transverse processes of the fifth lumbar vertebra may develop sufficiently to fuse with the sacrum.

(5) *Cervical rib*. The costal element of seventh cervical vertebra may have an additional primary centre of ossification and without fusing with the rest of the transverse process it may grow out sufficiently in the form of a rib to form the cervical rib.

(6) *Lumbar rib*. Similarly the first lumbar transverse process may grow out sufficiently to form the lumbar rib.

Errors of development of centrum. The single cartilaginous centrum occasionally has bilateral centres of ossification which normally should coalesce together. If any of its orinigal centre of ossification does not progress properly, formation of the vertebral body becomes defective, so that, at one side it becomes thicker, and on the other side thinner or deficient and as a result, the condition of permanent scoliosis (lateral flexion) occurs. The degree of scoliosis depends on the number of vertebrae involved. When both halves of the centrum develop improperly the condition of *kyphosis* (forward bending) results.

Other anomalies. (1) *Spondylolisthesis*—In this condition the fifth lumbar vertebra together with the whole vertebral column on the top of it is displaced forward on the sacrum and is associated with unusual strain on the sacro-iliac articulation giving rise to low back pain and other pressure symptoms.

(2) *Lumbarization of the first sacral vertebra*. In this the first sacral vertebra fails to fuse with the rest of the sacral mass. This condition is also associated with chronic low back pain.

THE STERNUM

General features. The sternum is the median bone on the anterior chest wall and is obliquely placed, so that, its anterior surface looks upwards and forwards. It is a long flat bone which is convex anteriorly in its general outline and is gently concave posteriorly. It is broad, expanded and thicker above and narrow and thinned out below. Its upper end, on each side, supports the clavicle and below that its each side articulates successively with the first seven ribs by means of costal cartilages which connect it with vertebral column. It consists of three segments—*the manubrium sterni, the body* and the *xiphoid process* which remain separated from one another for a considerable period of life and later on they are united together to form a single long flat bone. It is broadest above and then gradually narrows to a point where it joins with the body at an angle known as the *sternal angle*. The portion of the bone above the sternal angle is the *manubrium sterni*. Below this level its *body* gradually widens as far as the level where it articulates with the fifth costal cartilage and then quickly narrows again where it joins with the *xiphoid process*.

MANUBRIUM STERNI. The manubrium sterni forms the upper triangular segment of the sternum and is broader and thicker above than below. It consists of *anterior* and *posterior surfaces* and four borders—*superior, inferior* and two *lateral borders*. The *anterior surface* is smooth and is convex from side to side and gently concave from above downwards. The *posterior surface* is concave in its general outline. The *superior border* presents a shallow concavity opposite to the median plane and is known as the jugular notch (*suprasternal notch*). On either side of the jugular notch there is a large oval articular surface, the *clavicular notch* for articulation with the sternal end of the clavicle. The *inferior border* presents a small, oval facet which in the recent state is covered by a thin layer of cartilage and articulates with the upper end of the body forming a permanent (*secondary*) *cartilaginous joint*. Each *lateral border* presents a cup-shaped rough depression at its upper part for the reception of the first costal cartilage. The lower end of the lateral border presents a small articular facet which with a similar facet on the upper end of the lateral border of the body articulates with the second costal cartilage. The rest of the lateral border in between the articulations of the first and second costal cartilages is thin and slightly concave. The manubrium is widest opposite to the articular fossa for the first costal cartilage.

BODY OF THE STERNUM. The *body* of the sternum is longer and narrower than the manubrium and in early embryonic life consists of four sternal segments which afterwards are united together to form the body and the line of fusion is marked by transverse ridges on the anterior surface. It consists of *anterior* and *posterior* surfaces, two *lateral borders*, and an *upper* and a *lower end*. The anterior surface is flat and is marked by three transverse ridges which correspond to the line of fusion of the different sternal segments. An opening of varying size may be present opposite to the union between the third and the fourth sternal segments and is known as the *sternal foramen*. The posterior surface, which is slightly concave, also presents the transverse ridges but they are usually less distinct. Each lateral border presents four cup-shaped articular depressions for articulation with the third, fourth, fifth and the sixth costal cartilages from above downwards. The superior angle or the upper end of the body articulates with the manubrium sterni and forms an angle, the *sternal angle*. The small facet at the upper end of the lateral border together with a similar facet on the manubrium sterni forms a depression for the reception of the second costal cartilage. Its lower end articulates with the xiphoid process and the small facet at the angle of junction between it and the xiphoid process articulates with the seventh costal cartilage.

Particular features. The upper border of the manubrium sterni lies opposite to the lower border of the *second thoracic vertebra* while its lower border lies opposite to the lower border of the *fourth thoracic vertebra*. The jugular notch (*suprasternal notch*) from before backwards gives attachment to anterior of the two layers of the investing deep cervical fascia, interclavicular ligament (remains of episternal bar) and the posterior of the two layers of the investing deep cervical fascia.

lamellae of the investing layer of the deep cervical fascia being thus attached enclose a space between them known as the *suprasternal space* or *Space of Burns* which contains the *anterior jugular vein*, the arch of vein connecting the two anterior jugular veins (*jugular arch*), *interclavicular ligament*, the *sternal head of the sternocleidomastoid muscle*, *sternal lymph gland* and *some loose areolar tissue*. The *sternal angle* formed by the junction of the manubrium sterni and the body lies opposite to the level of the lower border of the fourth thoracic vertebra and articulates on either side with the second costal cartilage. It forms a bony prominence on the anterior chest wall and as the second costal cartilage articulates on its either side it is an important bony landmark for counting ribs.

Importance of sternal angle.

(1) It corresponds to the lower border of the fourth thoracic vertebra.
(2) It forms a landmark for counting ribs as the second costal cartilage articulates with sternum on either side opposite this angle.
(3) The arch of the aorta terminates into descending thoracic aorta at this level.
(4) The trachea bifurcates into bronchi at this level.
(5) It corresponds to the anterior margin of the plane that demarcates the superior and inferior mediastinums.
(6) It corresponds to the arch of the azygos vein.

The *clavicular notch* articulates with the sternal end of the clavicle by the intervention of an articular disc forming a plane type of synovial joint. Its circumferential margin gives attachment to the *capsular ligament* of the sternoclavicular articulation. Its anterior and posterior margins give attachment to the *anterior* and *posterior sternoclavicular ligaments* respectively. The cup-shaped depression at the upper end of the lateral border articulates with the first costal cartilage and the joint is a temporary (*primary*) *cartilaginous joint*.

The anterior surface of the manubrium on either side gives origin to *pectoralis major*. Close to its upper end this surface gives origin to the *sternal head of the sternocleidomastoid muscle* on either side of the median plane. Its posterior surface, immediately below the clavicular notch, gives origin to some fibres of the *sternohyoid* muscle. Below this, extending downwards and medially from the level of the first costal facet, the *sternothyroid* arises. In addition to the attachments of the above muscles the posterior surface is in relation to a host of important structures. It forms the anterior boundary of the superior mediastinum. The *arch of the aorta* is in relation to the lower-half of the posterior surface while its upper-half is in relation to the great vessels that are arising from the arch, and from right to the side, they are the *brachio-cephalic* (*innominate*), *left common carotid* and the *left*

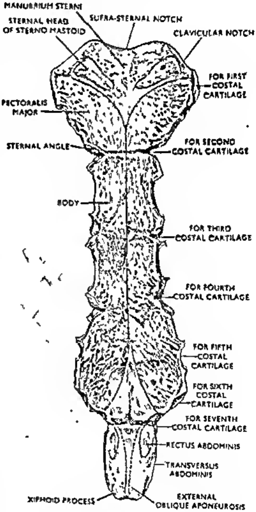


Fig. 241. The Sternum. Anterior view with attachments.

subclavian arteries; the *left brachio-cephalic* (*innominate*) *vein* also comes into relation with this part of the bone as it crosses in front of the roots of these great vessels. On either side it gives attachment to the *parietal pleura* and is in relation to the *anterior margin of the lung.* In front of the great vessels and in between the pleural attachments on either side it is related to the remains of the thymus gland; opposite the median plane in the upper half, it is related to trachea which appears between the divergence of the left common carotid and the left subclavian arteries.

The *body* of the sternum lies opposite to the fifth to the ninth thoracic vertebrae. Its anterior surface gives origin to *pectoralis major* on either side and is subcutaneous between these two muscles. The margins of the costal notches give attachment to the *capsular ligament of the sterno-costal articulations which are synovial joints.* Inferiorly the posterior surface, on either side, gives origin to the transversus thoracis (*sterocostalis muscle.*) Throughout its whole length, close to the right lateral margin, the posterior surface gives attachment to the *parietal pleura* and is in relation to the anterior margin of the right lung. On the left side the parietal pleura is attached to it *upto the level of the fourth costal cartilage.* Besides the above attachments the posterior surface of the body bears the following relations. On the right side it is in relation to the *anterior margin of the right lung* which separates it from the pericardium with the parietal pleura intervening. On the left side, upto the level of the fourth costal cartilage, it is in relation to the *anterior margin of the left lung*, and below this, it is in direct relation to the *pericardium* and gives attachment to the *anterior sterno-pericardial ligament.* The intervening margin between the costal notches gives attachment to the *external* (*anterior*) *intercostal membrane.*

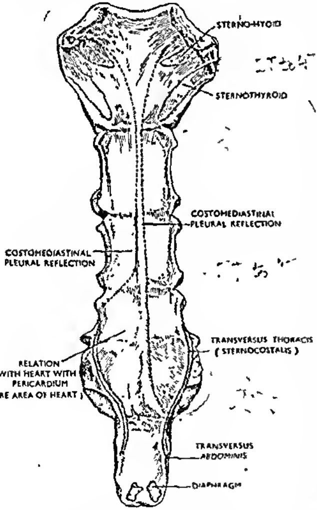


Fig. 242. The sternum. Posterior view with relation and attachments.

The *Xiphoid Process* lies in the floor of the epigastric fossa. It is about half the thickness of the body of the sternum and as its posterior surface is flush with the posterior surface of the latter (body of sternum) the xiphi-sternal articulation corresponds to a sharp transverse ridge anteriorly in the living subject and forms an important landmark.

It is usually irregular in its general outline. But it may be curved anteriorly, it may be bifurcated below or it may be diverted to one or the other side. Its anterior surface gives insertion to the medial fibres of the *rectus abdominis* on either side and to the aponeurosis of the *external oblique muscle* which covers the rectus abdominis in this situation. Its posterior surface gives origin to *diaphragm muscle* close to its tip, and on either side of its upper part, origin to some fibres of the transversus thoracis (*sternocostalis muscle*). The posterior surface of the xiphoid process is in relation to the *left lobe of the liver.* The lateral margin of the xiphoid process on either side gives insertion to *obliquus internus abdominis* and *transversus abdominis.* Its lower end gives attachment to the linea alba.

Importance of xiphi-sternal articulation. It forms an important median landmark on the lower part of the anterior chest wall and the seventh costal cartilage articulates with the sternum on either side; it corresponds to the lower surface of the heart, upper border of the midline dome of the diaphragm and the upper surface of the liver; the costal pleura is reflected on to the diaphragm anteriorly at this level. It corresponds to the lower border of the ninth thoracic vertebra.

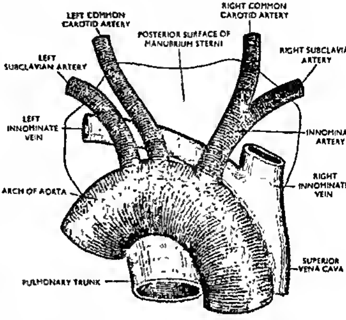


Fig. 243. The relations of the posterior surface of manubrium sterni.

Development. During early embryonic life the sternum consists of two plates of cartilages, one on each side of the median plane. The upper nine costal cartilages remain attached to each sternal plate at this stage and the two plates are connected together at their upper end by the episternal bar which also connects the two clavicles. By the eighth week of foetal life the sternal plates are united together to form the *cartilaginous sternum.* Subsequently the eighth costal cartilage usually loses its connection with the cartilaginous sternum. The ninth costal cartilage on each side splits into two parts, one remaining connected with the sternum and the other with the eighth costal cartilage; subseqently the portion connected with the sternum loses its connection with the ninth costal cartilage and gets fused with the fellow of the opposite side to form the xiphoid process. Defects in the union may result in the formation of a foramen in the xiphoid process or it may be forked inferiorly. Failure of fusion of the centres of ossification of the second, third or the fourth sternal segments of the body may result in the formation of sternal foramen.

Occasionally two small ossicles, the *suprasternal bones,* situated one on each side of the jugular (suprasternal) notch may be present. They are found to be attached to the articular disc of the sterno-clavicular joint. They are believed to represent the epicoracoid element of primitive girdle.

Ossification. The cartilaginous sternum is ossified from 6 centres, five primary and one secondary. The manubrium sterni and the body are ossified from primary centres whereas the xiphoid process is ossified from the secondary centre. The manubrium sterni is usually ossified from one primary centre which appears during sixth week of foetal life. The first segment of the body is usually ossified from one primary centre while in the lower three segments there may be two primary centres in each segment which are disposed bilaterally; the centres appear one after another from above downwards from seventh month to shortly before birth. The secondary centre for the xiphoid process appears during the third year of life and it unites with the body at the age of forty years. The manubrium unites with the body in extreme old age and the union is only superficial. The union between the different sternal segments beings at puberty from the lower segments and they are all united during the twenty-fifth year.

Structure of the sternum. The sternum is composed of outer and inner

compact layers together with an intervening layer of highly vascular spongy structure between these two compact layers.

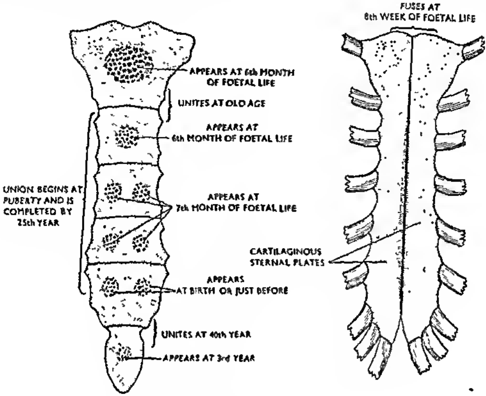


Fig. 244. The ossification of the sternum.

N. B. Sternal puncture is done by perforating the anterior compact layer of the manubrium sterni opposite to the median plane where it is subcutaneous and blood is withdrawn from the highly vascular spongy layer containing marrow for some pathological investigations (For Leishman Donovan bodies, anaemia, leukaemia etc).

RIBS (COSTAE)

Ribs are the elastic arches of flat bone which are twelve in number on each of the thoracic wall and are numbered from above downwards. The first seven pairs of ribs articulate, in front, with the sternum and behind, with the bodies of the first seven thoracic vertebrae and are called *true ribs* or *vertebro-sternal ribs.* The remaining five ribs are called *false* ribs because they have no direct connection with the sternum. The eighth, ninth and the tenth ribs articulate anteriorly with the costal cartilage of the rib above and posteriorly with the vertebral column and hence they may be called *vertebro-chondral* ribs. The eleventh and the twelfth ribs articulate posteriorly with the vertebral column but anteriorly they end in a free extremity and hence they may be called *vertebral ribs* or *floating ribs.*

Ribs

- True ribs or vertebro-sternal ribs (*First seven pairs of ribs*)
- *False* ribs (*Last five pairs of ribs*)
  - Vertebro-chondral ribs (8th, 9th and 10th ribs)
  - Vertebral ribs or floating ribs (11th and 12th ribs)

The ribs in the articulated skeleton contribute largely to the formation of the bony thoracic cage and form its anterior, posterior, and lateral walls. They are

situated one below the other in such a way that spaces are left between them which are known as *intercostal spaces* and the muscles, vessels and nerves that occupy this space are named accordingly as intercostal muscles, intercostal vessels and intercostal nerves respectively. Ribs are obliquely placed and hence the intercostal spaces are deeper in front than behind. They increase gradually in length from first to the seventh rib where it attains its maximum length, and below this, they again gradually diminish in length upto the last rib.

The *first*, *second*, *tenth*, *eleventh* and the *twelfth ribs* present special features and are called atypical or *peculiar ribs* and the remaining ribs maintain common features and are known as *typical ribs*.

TYPICAL RIBS

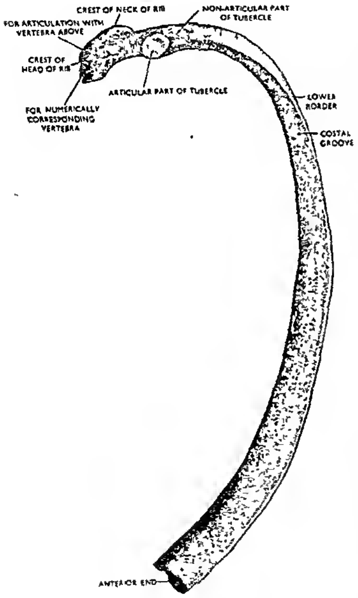


Fig. 245. A typical rib of right side. Inferior aspect.

General features. Each typical rib consists of an *anterior* and a *posterior* end and an intervening portion known as the *body* or *shaft*.

The ANTERIOR END presents a cup-shaped depression which articulates with the corresponding costal cartilage.

The POSTERIOR END consists of a *head*, a *neck* and a *tubercle*. The *head* presents two small facets —upper and lower, separated from each other by a ridge known as the *crest* of the head. The lower facet of the head articulates with a similar facet on the body of the numerically corresponding vertebra whereas the upper facet articulates with the vertebra above. The crest corresponds with the intervertebral disc. The *neck* is flattened from before backwards and just succeeds the head. It measures about one inch in length and lies opposite to the transverse process of the corresponding vertebra. It consists of anterior and posterior surfaces and upper and lower borders. The anterior surface of the neck is smooth and is directed upwards and forwards. Its posterior surface looks downwards and backwards and is rough. It is pierced by

numerous vascular foramina. The upper border of the neck is raised, sharp and prominent and is called the *crest* of the neck. Its lower border is smooth and rounded. The *tubercle* of the rib is placed on the lateral part of the posterior surface of the neck and marks the line of demarcation between the neck and the body. It is divisible into a medial articular portion and a lateral non-articular portion. The medial articular portion presents a facet which articulates with a similar facet on the transverse process of the numerically corresponding vertebra.

The *body* or *shaft* of the rib is flat and consists of an outer or external surface, an inner or internal surface and superior and inferior borders. It is curved on itself and its inner surface is concave and its outer surface is convex. It is also bent and twisted on itself and at the point of bending it forms an angle on its external surface known as *the angle* of the rib which lies at a distance of about 2 inches from the tubercle. Due to the twisting, the external surface of the posterior part of the body looks downwards and laterally and its internal surface looks upwards and medially. Opposite to the angle of the rib the external surface is marked by an oblique ridge directed downwards and laterally. Close to the lower border of the internal surface there is a groove known as the *costal groove* which is bounded below by the lower border of the shaft and above by a raised margin which is continuous with the lower border of the neck posteriorly. Anteriorly this ridge or margin cannot be traced beyond the junction of the middle and the anterior-third of the rib and the costal groove is deficient beyond this point. The *inferior border* of the rib is sharp and forms the inferior margin of the costal groove. The *superior border* of the shaft is rounded and is divisible into outer and inner lips which are indistinctly marked close to its anterior extremity.

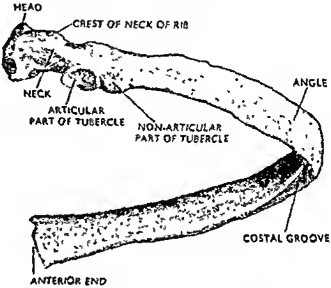


Fig. 246. A typical rib of right side. Posterior aspect.

Particular features. The circumferential margin of the head gives attachment to the *capsular ligament* of the costovertebral joint. Its anterior margin and the adjoining anterior surface of the neck give attachment to the *radiate ligament* which connects the rib with the numerically corresponding vertebra and with the vertebra above. The crest of the head gives attachment to the *intra-articular ligament* which connects it with the intervertebral disc. The anterior surface of the neck is marked above by a ridge which extends laterally to become continuous with the inner lip of the superior border of the shaft. This ridge gives attachment to the *internal (posterior) intercostal membrane* and subdivides the anterior surface into upper smaller and lower larger areas; the upper area is covered by a pad of fat while the lower area is covered by the parietal pleura. In the lower ribs this surface adjoining the anterior margin of the head is crossed by the sympathetic trunk; the posterior surface of the neck gives attachment to the *inferior costo-transverse ligament.* The crest of the neck gives attachment to the *superior costo-transverse ligament.* It is continuous laterally with the outer lip of the superior border of the shaft; the inferior border of the neck is rounded and gives attachment to the *internal (posterior) intercostal membrane.* The non-articular part of the tubercle gives attachment to the *lateral costo-transverse ligament.*

The ridge which marks the position of the angle on the external surface of the body gives attachment to the *lumbar fascia* and to the lateral fibres of the *ilio-costocervicalis.* The area between the tubercle and the angle gives insertion to *levator costarum* and is covered by *sacrospinalis.* Close to the anterior end the external surface is marked by a faint ridge (which marks the anterior angle) and the area in front of this ridge gives origin to *obliquus externus abdominis* and the area behind it gives origin to *serratus anterior* (3rd to 8th rib) and to *latissimus dorsi* in case of 9th and 10th ribs. The upper margin of the costal groove gives origin to *intercostalis intimus,* its floor to *intercostalis internus* and its lower border to *intercostalis externus.* The costal groove lodges the *intercostal vein, intercostal artery* and the *intercostal nerve* from above downwards The inner lip of the superior border gives insertion to *intercostalis internus* and *intimus;* its outer lip gives insertion to *intercostalis externus.*

THE FIRST RIB

Special features. (1) It is most curved and its **surfaces** are superior and inferior. (2) The **head** is small and bears only a single facet which articulates with the upper part of the body of the first thoracic vertebra. (3) The **neck** is rounded and is directed upwards, backwards and laterally. (4) The **angle** of the first rib coincides with the tubercle and the bone is bent at this point and the head is directed downwards, forwards and medially. The tubercle is very prominent and bears only the articular surface. (5) The superior surface of the body is rough and irregular and on it there are two grooves separated from each other by an indistinct ridge which ends medially into a tubercle known as the *scalene tubercle* situated on the inner border of the rib. (6) Its **borders** are outer and inner; the outer border is convex and the inner border is concave. (7) The inferior surface is smooth and there is **no costal groove.**

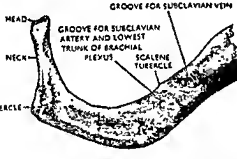


Fig. 247 The right first rib. Superior aspect.

Identification of sides. Hold the bone in such a way that its upper rough surface carrying two grooves looks upwards, the expanded anterior extermity looks forwards and downwards, the small head looks downwards, forwards and medially and the outer convex margin will determine the side to which the bone belongs (place the bone on a plane surface and if the two ends of the bone touch the surface know that the inferior surface lies against the flat surface).

Particular features. The margins of the facet on the head give attachment to *capsular ligament* of the first costo-vertebral joint. The anterior margin of the head gives attachment to *radiate ligament,* the posterior margin of the neck to *inferior costo-transverse ligament,* superior margin to *superior costo-transverse ligament* and the lateral part of the tubercle to *lateral costo-transverse ligament.* From lateral to the medial side the anterior aspect of the neck of the first rib is in relation with the first thoracic nerve, the first posterior intercostal vein, the superior intercostal artery and the sympathetic trunk together with the first thoracic ganglion (stellate ganglion); the anterior primary ramus of the first thoracic nerve ascends upwards to join the brachial plexus; the superior intercostal artery from the costo-cervical trunk and the sympathetic trunk descend downwards; the first posterior intercostal vein ascends upwards to terminate either in the left brachio-cephalic (innominate) vein or in the left vertebral vein. The apex of the lung lies in front of the neck being separated by the parietal pleura.

The anterior of the two grooves on the upper surface lodges the subclavian vein and the posterior groove lodges the subclavian artery and the lowest trunk of the

brachial plexus. The rough area in front of the anterior groove gives origin to subclavius laterally and attachment to costoclavicular ligament medially. The scalene tubercle together with the faint ridge on the upper surface gives insertion to *scalenus anterior*. The rough area behind the posterior groove gives insertion to *scalenus medius* and extends up to the tubercle. A narrow strip of hone adjoining the outer border and lying opposite to the posterior groove gives origin to a part of the *first digitation* of the *serratus anterior;* the inner border throughout its whole length gives attachment to *suprapleural membrane* (Sihson's fascia), a strong layer of fascia which extends from the transverse process of the seventh cervical vertebra to the inner border of the first rib and covers the cervical dome of the pleura. The inferior surface is smooth and close to the outer border it gives origin to *intercostalis externus* and *internus*, the externus being outer and the internus inner. The rest of the inferior surface is covered by the costal pleura.

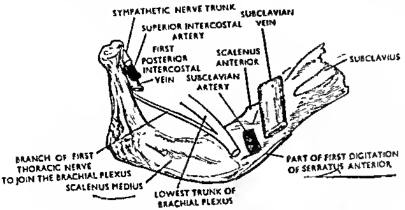


Fig. 248. The right first rib. Superior aspect with attachments and relations.

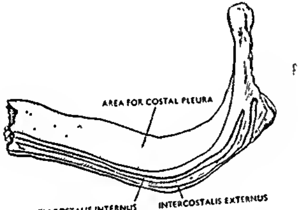


Fig. 249. The right first rib. Inferior aspect with attachments and relations.

SECOND RIB

General features. The second rib is about twice the length of the first rib; the head is small and carries two facets which may not be very distinct. The neck is small and the tubercle is divisible into articular and non-articular parts, the non-articular part being comparatively small. There is a faint angle and the surfaces of the body are external and internal; the external surface looks more superiorly than externally and the internal surface looking more inferiorly than internally. Opposite to the middle of the external surface there is a rough muscular impression. The internal surface is smooth and concave; close to its posterior part this surface presents a faint costal groove. There is *no twisting* in this bone; so when it is placed on a flat surface both its ends touch the surface.

Particular features. The posterior end of the second rib has the same attachments as that of the typical rib. The rough impression on the external surface gives origin to the lower part of the first and the whole of the second digitation of the *serratus anterior;* more close to the outer border and between the rough impression

and the tubercle the area gives insertion to *scalenus posterior* anteriorly and *serratus posterior superior* posteriorly; in addition it has the same attachment as that of the typical ribs.

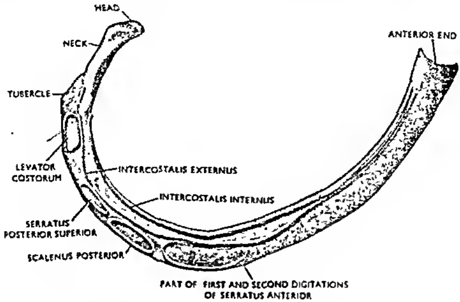


Fig. 250. The right second rib Superior aspect with attachments.

Tenth rib. The tenth rib bears all the characteristics of a typical rib except that *it has a single articular facet on the head.*

Eleventh rib. The eleventh rib bears the following special features:

(1) It bears *a single facet on the head.*
(2) It has *no neck* and *no tubercle.*
(3) There is a *faintly marked 'angle'* on the outer surface.
(4) It bears a *faintly marked costal groove* on its internal surface.
(5) Its anterior extremity is pointed.

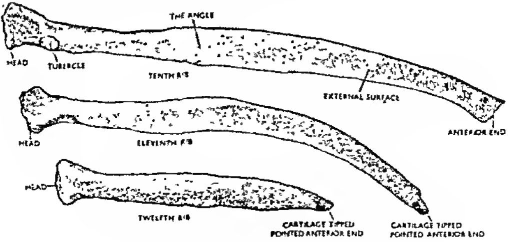


Fig. 251. The right 10th, 11th and 12th ribs from above downwards. Outer aspects.

Twelfth rib. Characteristic features

(1) It has *a single facet on its head.*
(2) Its anterior end is pointed.
(3) It has *no neck, no tubercle, no angle* and *no costal groove.*

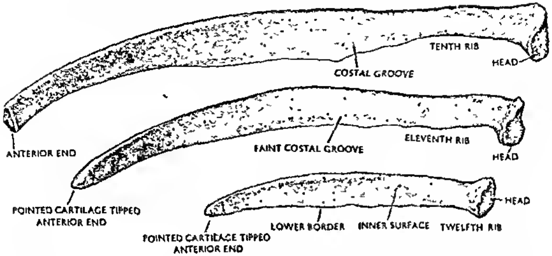


Fig. 252. The right 10th, 11th and 12th ribs from above downwards. Inner aspects

Side determination. Hold the bone in such a way that its pointed end looks forwards and laterally, its head looks backwards and medially, its concave anterior or internal surface looks *upwards* and *medially* and the convex lateral surface which looks downwards and laterally will determine the side to which the bone belongs. (This same principle is also applicable to the side determination of the eleventh rib).

Particular features. The lower part of the anterior or internal surface of the medial half of the twelfth rib gives insertion to *quadratus lumborum* and attachment to the anterior lamella of the lumbar fascia above the muscle. The lateral arcuate ligament which is a thickened oblique band is attached to the lower border of the twelfth rib lateral to the quadratus lumborum and extends obliquely downwards and medially across the front of the quadratus lumborum for gaining its attachment to the front of the transverse process of the first lumbar vertebra. The costal pleura is attached to its anterior surface along a line which passes obliquely downwards from the upper border lateral to the head to the level of the upper attachment of the quadratus lumborum and then passes laterally and upwards to gain the upper border again just medial to the tip. Thus the anterior surface close to the tip is devoid of pleural attachment. The area of the anterior surface above the line of attachment of the costal pleura is in relation with the costo-diaphragmatic recess of the pleural sac. Its posterior or external surface in its medial half gives attachment to lowest *levator costae, longissimus thoracis* and *ilio-costalis* in order from medial to lateral side. Its lateral half gives attachment to *serratus posterior inferior, latissimus dorsi* and *obliquus externus abdominis* in order from medial to lateral side. Its upper border gives insertion to *intercostalis internus* and *externus;* its lower border close to the head gives attachment to the *lumbocostal ligament* and to the rest of its extent it gives attachment to the *middle lamella of the lumbar fascia.*

Anteriorly the twelfth rib is in relation to the posterior surface of the kidney and the subcostal vessels and nerve lie along its lower border.

Structure of ribs. A rib is composed of highly vascular spongy bone internally and is surrounded by a tube of compact bone externally. The internal compact layer is thicker and stronger than the external one and both the layers become thickest and strongest opposite the angle of the bone; the compact bone overlying the borders is comparatively thinner than that lines the surfaces. The nutrient canal begins in the costal groove and proceeds towards the vertebral end.

Ossification. The main portion of each rib develops from one primary centre which appears in the region of the angle during the sixth week of foetal life and then spreads in both the directions. The first, seventh, eighth, ninth and the tenth

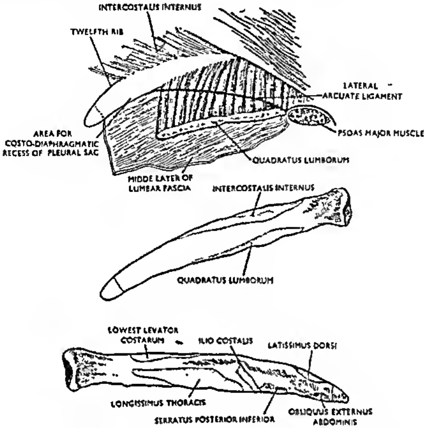


Fig. 253 The right 12th rib. Inner (upper two) and outer aspects (lower) with attachments.

ribs each has got two epiphyses, one for the head and one for the tubercle which ossify from secondary centres of ossification. From second to sixth ribs, each has three epiphyses, one for the head, one for the non-articular part of the tubercle and the other for the articular part of the tubercle. The eleventh and the twelfth rib each has only one epiphysis for the head. Ossification begins in the epiphyses of the ribs at puberty and they fuse with the rest of the bone at 25th year of life.

THE THORAX AS A WHOLE

The osseo-cartilaginous framework of the chest constitutes the thorax which encloses a cavity for the lodgement of the heart and lungs with great vessels, nerves and trachea and oesophagus and other structures. It is conical in shape being narrow above and broad below. Due to projection forwards of the vertebral bodies the thoracic cavity appears to be kidney-shaped on transverse section. However, its shape varies with age, sex and bodily habitus.

A birth both the antero-posterior and transverse diameters are almost equal while in the foetus the antero-posterior diameter is larger than the transverse diameter. The relation between these two diameters is expressed by $\frac{\text{transverse diameter} \times 100}{\text{Antero-posterior diameter}}$ and is known as thoracic index. In the foetus it is below 100 and in the adult it varies between 130 and 135 (Frazer).

It presents for examination an inlet, an outlet and four walls, anterior, posterior and two lateral.

Inlet of thorax. The superior aperture of the thorax is known as its inlet. It is bounded in front by the upper border of the manubrium sterni and the first costal cartilages, behind by the body of the first thoracic vertebra and on either side by the first rib. The *plane of the inlet* is oblique in direction; it inclines downwards and forwards, so that, its anterior boundary is much lower than its posterior boundary; the latter corresponds to the body of the first thoracic vertebra whereas its anterior boundary corresponds to the disc between the bodies of the second and the third thoracic vertebrae.

Structures passing through the inlet are apices of the lungs and pleura, trachea, oesophagus, phrenic, vagus, cardiac nerves and the sympathetic nerve trunks, superior intercostal, left subclavian, left common carotid and terminal part of the brachiocephalic (Innominate) arteries, right and left brachiocephalic veins and thoracic duct.

Outlet of thorax. It is much larger than the inlet and is bounded behind by the body of the twelfth thoracic vertebra, in front by the cartilages of 10th, 9th, 8th and 7th ribs and on each side by 11th and 12th ribs. The outlet or the inferior aperture of the thorax is closed by the diaphragm muscle in the recent state.

The thoracic cavity. It is bounded in front by the sternum with costal cartilages, behind by the bodies of the thoracic vertebrae together with the posterior ends of the ribs, and on either side, by the ribs. Posteriorly on either side of the vetebral column there is a gutter, the *pulmonary groove*, which is occupied by the posterior thick border of the corresponding lung.

Three diameters—namely, vertical, transverse and antero-posterior, are taken into consideration in respect of the thoracic cavity. The *vertical diameter* is measured from inlet to the outlet; the *transverse diameter* can be measured from the centre of a given intercostal space to the centre of the same space on the opposite side. The *antero-posterior diameter* extends from anterior to the posterior wall; it is smaller in the median plane than that opposite the paravertebral gutter.

Sexual differences. In the female the thorax is shorter, less capaceous and is made up of bones which are lighter. The sternum is shorter in the female and its upper border corresponds to the lower border of the third thoracic vertebra whereas in the male it corresponds to the disc between second and third thoracic vertebrae; the upper thorax is more movable in the female.

THE COSTAL CARTILAGES

The costal cartilages are twelve in number on each side and each is connected to the anterior end of the corresponding rib. The first seven pairs connect the corresponding ribs with the sternum while the eighth, ninth and tenth cartilages fail to reach the sternum and each is united with the lower border of the cartilage above by synovial joints. The eleventh and twelfth costal cartilages are mere nodules of cartilages tipping the corresponding ribs and they remain free without having any connection between themselves. In length, breadth and direction the costal cartilages vary considerably. They gradually increase in length from above downwards upto seventh costal cartilage and then gradually diminish in length to the twelfth. In breadth they gradually diminish from first to the last costal cartilages. The second costal cartilage is horizontal in direction, the first inclines downwards while the third slightly ascends upwards. The remaining costal cartilages are bent on themselves so that their costal ends descend while their sternal ends ascend upwards, in other wards, each has an angular bend the point of which is directed downwards.

Each costal cartilage has two ends, two borders and two surfaces. The *medial ends* of the first seven costal cartilages are connected to the sternum at the costal notches, the first one by synchondrosis and the others by synovial joints. The medial ends of the eleventh and twelfth are free; those of the eighth, ninth aod

tenth costal cartilages are pointed and are connected to each other by synovial joints. The *lateral ends* of the costal cartilages are continuous with the corresponding ribs, the periosteum of the ribs being continuous with the perichondrium of the cartilages. The surfaces are *anterior* and *posterior*. The anterior surface of each costal cartilage is convex and is directed forwards and upwards. The *anterior surface* of the first costal cartilage gives attachment to the articular disc of the sternoclavicular joint, costoclavicular ligament and origin to the subclavius muscle. Close to the medial ends the anterior surfaces of the first seven costal cartilages give origin to pectoralis major muscle and the anterior surfaces of the rest give attachment to the flat muscles of the abdomen. The *posterior surface* of each cartilage is concave and is directed downwards and backwards. The posterior surface of the first costal cartilage gives origin to sternothyroid muscle. The posterior surfaces of the succeeding cartilages upto sixth give origin to transversus thoracis (sternocostalis) while those of the lower six give origin to transversus abdominis and diaphragm muscles. The *borders* of each costal cartilage are *superior* and *inferior*. The *superior border* is concave while the *inferior border* is convex. Both the superior and inferior borders give attachments to internal intercostal muscles and external intercostal membranes. The lower or inferior borders of sixth, seventh, eighth and ninth cartilages are bent on themselves and at their point of maximum bend each presents a conical projection which articulates by an oblong facet with the projection on the upper border of the cartilage below.

In advanced age the costal cartilages undergo superficial ossification underneath the perichondrium and thus a thin shell of bone is formed around it.

THE SCAPULA

The scapula is a large triangular *flat bone* situated on the postero-lateral aspect of the upper part of the thorax and extends from the second to the seventh rib. It presents for examination *costal* and *dorsal* surfaces, *superior, medial* and *lateral* borders and three processes—the *spine* and its continuation, the *acromion*, and the *coracoid* process, and three angles, *superior, lateral* and *inferior*. The most conspicuous feature of the dorsal surface is the presence of the spine which projects backwards and is continued lateralwards as an expanded plate known as the *acromion*. Its costal surface is hollowed out and looks forwards and medially. Its lateral angle is truncated and presents a pear-shaped articular surface known as the *glenoid cavity* which articulates with the head of the humerus. The apex of this triangular plate of bone which is formed by the union of the lateral and medial borders is known as the *inferior angle* and is directed downwards.

Side determination. Hold the bone in such a way that its dorsal surface carrying the spine and the acromion looks backwards, its inferior angle looks downwards and the glenoid cavity which is directed forwards, laterally and slightly upwards will determine the side to which the bone belongs.

General features. The LATERAL OR AXILLARY BORDER is the thickest of all and begins from the lower part of the glenoid cavity, and descending vertically downwards it ends at the inferior angle. Just below the glenoid cavity this border presents a rough impression known as the *infraglenoid tuberosity*. The MEDIAL OR THE VERTEBRAL BORDER is the longest of all and begins from the superior angle above and ends below in the inferior angle. The SUPERIOR BORDER is the thinnest and shortest of all and begins from the superior angle and passing horizontally lateralwards it ends into a notch, the *suprascapular notch*, which separates it from the root of the coracoid process.

The INFERIOR ANGLE is formed by the union of the lateral and medial borders and is directed downwards; it *lies opposite to the seventh rib*. The SUPERIOR ANGLE is formed by the union of the superior and medial borders and is directed upwards and medially. The LATERAL ANGLE corresponds with the glenoid cavity and is broad and forms the *head* of the scapula; immediately above the glenoid cavity, close to the root of the coracoid process,

there is a rough impression known as the *supraglenoid tubercle.* Just succeeding the head, the constricted portion of the bone beyond the glenoidal margin constitutes its *anatomical neck;* it corresponds to a line passing from above the infraglenoid tuberosity to the root of the coracoid process adjoining the supraglenoid tuberosity. The *Surgical neck* corresponds to a line passing from the anterior margin of the suprascapular notch to the infraglenoid tuberosity.

The COSTAL SURFACE is concave and hollowed out and is directed forwards and medially. Close to the lateral border it presents a rounded vertical ridge which is separated from the lateral border by a shallow vertical groove. From opposite to the level of the spine this surface presents a series of oblique ridges which give attachment to the intramuscular tendon. The *dorsal surface* is divided into a smaller *upper area* and a larger *lower area* by the shelf-like bony projection known as the *spine.* The upper area is known as the *supraspinous fossa,* whereas the lower area is known as the *infraspinous fossa* and these two fossae communicate with each other through a notch —the *spino-glenoid notch* (great scapular notch)—formed by the free lateral border of the spine and the dorsal surface of the neck of the scapula. Close to the lateral border the dorsal surface is marked by a flattened strip which separates the axillary border from the infraspinous fossa; this flattened strip is narrower above and is broader below. A vertical margin separates this strip from the infraspinous fossa and this strip is divided by an oblique ridge into upper and lower areas.

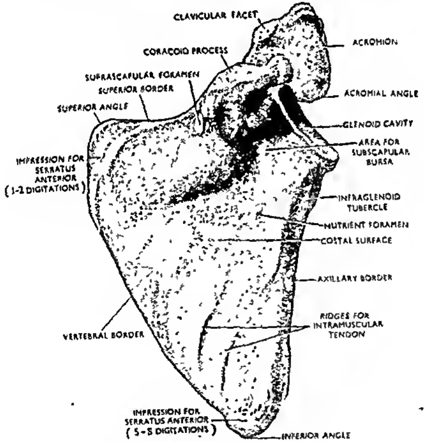


Fig. 254. The left scapula. Ventral aspect.

The SPINE of the scapula forms a shelf-life projection from the upper part of the orsal surface and is triangular in shape. It consists of *anterior, posterior* and *lateral orders,* and *upper* and *lower surfaces.* The *anterior border* is fused with the dorsal surface f the scapula obliquely upwards and laterally. The *posterior border* is considerably hick and is known as the *crest* of the spine. The crest of the spine is divisible into *pper* and *lower lips* and *an intervening area.* Close to the vertebral border the lips of

the crest diverge from each other and enclose a smooth triangular area. The *lateral border* of the spine is thick and rounded and is continuous above with the under surface of the acromion; together with the dorsal surface of the neck it forms the spinoglenoid notch. The *upper surface* of the spine is gently concave and is con-

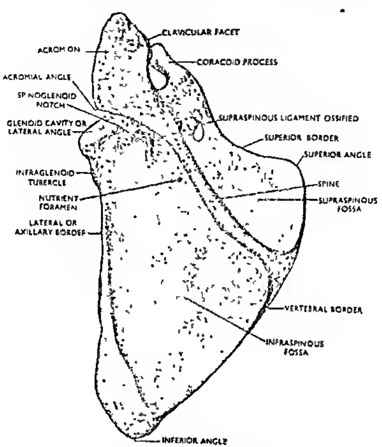


Fig. 255. The left scapula. Dorsal aspect

tinuous with the supraspinous fossa. Its *lower surface* is slightly convex and is continuous with the infraspinous fossa.

The Acromion is the expanded plate of bone which extends laterally from the spine and overhangs the glenoid cavity; the long axis of the acromion meets the long axis of the spine at an angle which measures a little more than 90°. It consists of *lateral* and *medial* borders and *superior* and *inferior* surfaces. The lateral border is rough and knobbed and meets the lower lip of the spine to form an angle—the *acromial angle*—which forms a subcutaneous bony prominence. Its medial border presents a small articular facet for articulation with the lateral end of the clavicle. Its *upper surface* is rough and subcutaneous; its *inferior surface* is smooth and forms a greater part in the formation of the coraco-acromial arch.

The coracoid process of the scapula arises from the upper part of the head and intervenes between the suprascapular notch and the upper end of the glenoid cavity. At first it ascends slightly upwards and medially and then abruptly bends forwards and laterally. Thus it may be divisible into *ascending* and *horizontal portions;* the *ascending part* is broad, short and stout and its anterior surface is smooth and concave; its dorsal surface is rough and presents a rough impression where it meets the horizontal part. *The horizontal portion* projects forwards and is twisted and presents *lateral and medial borders* and *upper and lower* surfaces and a *conical extremity* or

end. Its *lateral border* is smooth whereas its *medial border* is rough. Its upper surface is also rough whereas its lower surface is smooth.

Particular features. The whole of the costal surface except the roughened strip opposite to the vertebral border and except over a small area adjoining the neck gives origin to the *subscapularis* muscle which extends over to the rounded ridge and the groove adjoining the axillary border. The oblique ridges give attachment to the *intramuscular tendon.* The smooth hollow opposite to the neck is occupied by the *subscapular bursa* which intervenes between the bone and the subscapularis tendon. The roughened strip opposite to the vertebral border which extends on to the ventral aspect of the inferior angle, gives insertion to *serratus anterior* muscle. The first and second digitations extend from the superior angle to a point opposite to the apex of the spine, below that up to the upper part of the inferior angle it receives the third and the fourth digitations and the oval impression opposite to the inferior angle receives fifth to the eighth digitations.

The SUPRASPINOUS FOSSA gives origin to *supraspinatus muscle;* the margin separating the infraspinous fossa from the flattened strip gives attachment to *intermuscular septum* which separates the infraspinatus from the teres major et minor. The upper part of the flattened strip gives origin to *teres minor,* and its lower part to *teres major* and the oblique ridge separating these two areas gives attachment to the *intermuscular septum* between the teres major et minor. A transverse groove crosses the upper area and transmits the *circumflex scapular vessels* which intervene between the teres minor and the bone. The infraspinous fossa gives origin to *infraspinatus muscle.* The dorsal surface of the inferior angle gives origin to some fibres of the *latissimus dorsi.*

The LATERAL BORDER is thick and is overlapped behind by the teres major et minor and in front by the subscapularis. The infraglenoid tubercle gives origin to the *long head of the triceps brachii.* The VERTEBRAL BORDER is bent opposite to the apex of the spine. From the superior angle to the upper part of the apex of the spine the

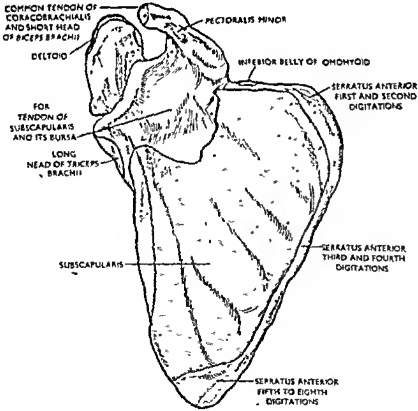


Fig. 256. The right scapula. Ventral aspect with attachments.

dorsal aspect ot the vertebral border gives insertion to *levator scapulae*, opposite to apex it gives insertion to *rhomboideus minor* and below that up to the inferior angle it gives insertion to *rhomboideus major*. The SUPERIOR BORDER of the scapula is thin and short and near the suprascapular notch it gives origin to the *inferior belly of omohyoid*. The margins of the suprascapular notch give attachment to the *suprascapular ligament* which converts the suprascapular notch into *suprascapular foramen* which transmits the *suprascapular nerve;* the suprascapular vessels cross over the suprascapular ligament to enter into the supraspinous fossa.

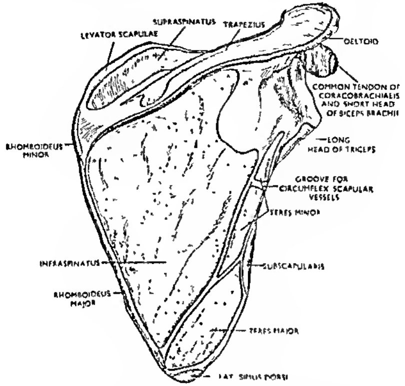


Fig. 257. The right scapula. Dorsal aspect with attachments.

The INFERIOR ANGLE of the scapula lies opposite to the seventh rib and its dorsal surface gives origin to some fibres of the *latissimus dorsi* and its ventral surface gives insertion to lower four or five digitations of the *serratus anterior*. The SUPERIOR ANGLE is covered by the trapezius muscle. The LATERAL ANGLE is truncated and presents a pear-shaped articular surface known as the glenoid cavity which articulates with the head of the humerus and forms the shoulder joint which is a "ball and socket" sub-group of the synovial joint. The margins of the glenoid cavity give attachment to the *glenoidal labrum*. The supraglenoid tubercle at the root of the coracoid process gives origin to the *long head of the biceps brachii*. The capsular ligament of the shoulder joint is attached to the circumferential margin of the glenoid cavity beyond the glenoidal labrum; superiorly, it extends to the root of the coracoid process so as to enclose the origin of the long head of biceps brachii within its attachment; although the long tendon of biceps brachii is intracapsular it is always extra-synovial, that is, it lies outside the lining of the synovial membrane.

The upper and the lower surfaces of the SPINE give origin to *supraspinatus* and *infraspinatus* respectively; the lower lip of the crest gives origin to *deltoid muscle*. Its upper lip gives insertion to the lowest fibres of *trapezius* which extends into dorsal subcutaneous area for a small extent close to the apex of the spine; the intevening area is subcutaneous; the triangular area opposite to the apex of the spine is covered by the tendon of the trapezius muscle and a *bursa* intervenes between the tendon and

the bone. The lateral border of the spine together with the dorsal surface of the neck forms the spinoglenoid notch which transmits the *suprascapular vessels* and *nerves* to the infraspinous fossa.

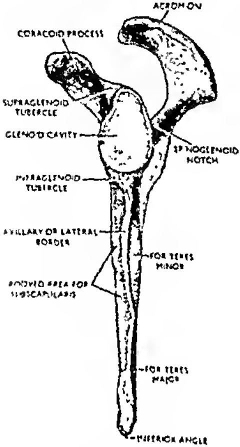


Fig. 258. The lateral view of left scapula.

The superior surface of the ACROMION is subcutaneous; its lateral border gives origin to the *deltoid muscle.* The tip of the acromion gives attachment to *coracoacromial ligament.* Its medial margin presents an articular facet which articulates with the lateral end of the clavicle; the margins of the facet give attachment to the *capsular ligament* of the *acromio-clavicular joint.* Behind the articular facet the medial border gives insertion to the middle fibres of the *trapezius muscle.* The over-hanging acromion, the coracoacromial ligament and the coracoid process, all together form an arch—the coracoacromial arch which supports the head of the humerus when the arm is fully abducted and prevents its upward displacement. The tendon of the supraspinatus muscle passes through the arch before its insertion and is separated from the inferior surface of the acromion by the *subacromial bursa.*

The CORACOID PROCESS of the scapula projects forwards and lies below the junction of the lateral one-fourth with the medial three-fourths of the clavicle. The hollowed out anterior surface of its ascending part is occupied by the *subscapular bursa* and the *tendon of the subscapularis muscle.* Its posterior surface is crossed by the tendon of the *supraspinatus* and the rough impression at the junction of the ascending and the horizontal parts gives attachment to the *conoid part* of the *coracoclavicular ligament* (derived from precoracoid element) while its *trapezoid part* is attached to the ridge on the upper surface of the horizontal part. The margin of the *suprascapular notch formed* by the ascending part gives attachment to the *suprascapular ligament.* The lateral border of the horizontal part gives attachment to the *coracoacromial* ligament both in front and behind, and in the middle, it gives attachment to the *coracohumeral ligament* (Divorced tendon of pectoralis minor). The medial border of the horizontal part and the adjoining upper surface give insertion to the *pectoralis minor.* The tip of the coracoid process gives origin to the common tendon of *coracobrachialis* and the *short head of the biceps brachii*, the coracobrachialis being medial and the short head of the biceps brachii being lateral.

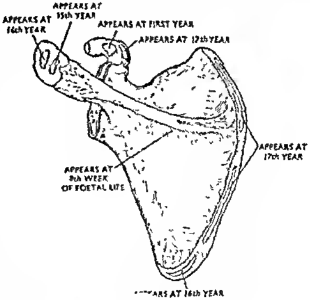


Fig. 259. Centres of ossification of scapula.

Ossifications. The scapula ossifies from *two primary* and *seven secondary centres.* The primary centre for the body appears in the region of the neck during the eighth week of foetal life and forms a triangular plate of bone. The primary centre for the coracoid process appears in the first year. The spine appears as a ridge on this triangular plate of bone during the third month. At birth the glenoid cavity, the coracoid process, the acromion, the vertebral border and the inferior angle are cartilaginous. Two secondary centres in the acromial cartilage, one close to the base and the other close to the tip, appear during the fifteenth and the sixteenth years respectively and soon fuse to form the acromion which joins with the spine at twentieth year. Secondary centre for the root of the coracoid process including the upper portion of the glenoid cavity (subcoracoid) appears at the seventeenth year. The secondary centre for the vertebral border appears at the seventeenth year. The secondary centre for the inferior angle appears at the sixteenth year. The lower part of the glenoid cavity is covered with a horse-shoe shaped cartilage, the secondary centre for which appears during puberty. All the secondary centres fuse with the body by the twenty-fifth year.

THE CLAVICLE

The clavicle is one of the long bones but it differs from other long bones in that it has *no medullary cavity* and it *develops from membrane.* It is situated in front of the root of the neck and somewhat resembles the letter '*f*' being convex anteriorly in its medial two-thirds and concave anteriorly in its lateral one-third. Its lateral one-third is *flat* while its medial two-thirds are *cylindrical* in shape. The inferior surface of the middle-third of the bone is grooved and opposite to the junction of the medial three-fourths with the lateral one-fourth on the *postero-inferior part* of the bone there lies the *conoid tubercle.*

Side determination. Hold the bone in such a way that its convex anterior surface of the medial two-thirds and the concave anterior margin of the lateral one-third look forwards, the grooved inferior surface looks downwards, the conoid tubercle lies on the *postero-inferior part* of the bone and the flattened acromial end will determine the side to which the bone belongs.

General features. Lateral one-third of the clavicle. The lateral one-third of the clavicle is flat and its surfaces are *superior* and *inferior* and its borders are *anterior* and *posterior.* The *anterior border* is convave and rough and may present a small tubercle known as the *deltoid tubercle.* The *posterior border* is thick and convex. The *superior surface* is rough both anteriorly and posteriorly but it is smooth in the intervening area which is subcutaneous. The *inferior surface* is rough and presents the *conoid tubercle* close to its posterior border opposite to the junction of the medial three-fourths with the lateral one-fourth of the bone. From the conoid tubercle an oblique, rough ridge extends forwards and laterally to the acromial end and is known as the *trapezoid ridge.*

Medial two-thirds of the clavicle. The medial two-thirds of the clavicle present four surfaces, namely *anterior, posterior, superior* and *inferior.* The *anterior surface* is convex in its general outline and is rough for muscular attachment. The *posterior surface* is concave and is smooth and featureless. The *superior surface* is rough in its medial part but is smooth in its lateral part. The *inferior surface* presents a rough impression, the *costal impression,* close to its sternal end and in the rest of its extent it is grooved and is known as the *subclavian groove.*

The acromial or the lateral end of the clavicle presents a small oval facet for articulation with a similar facet on the medial border of the acromial process of the scapula.

The sternal end of the clavicle is thickened and presents a large articular surface which is convex in all directions and is rough for the attachment of the articular disc. It articulates with the clavicular notch of the sternum by the intervention of an articular disc. The lower part of the articular surface is prolonged on to the inferior aspect of the bone for a small extent where it articulates with the upper surface of the first costal cartilage.

capitate bone. The proximal surface of the base articulates with the hamate bone. The strip-like facet on the medial aspect of the base articulates with the fifth metacarpal bone. The lateral surface of the shaft is divided into a volar and a dorsal area by a ridge. The volar area gives origin to the *third palmar interosseous muscle*, while the dorsal area gives origin to the *medial head of the third dorsal interosseous*. The medial surface of the shaft gives origin to the *radial head* of the *fourth dorsal interosseous muscle*.

Side determination. Hold the bone in such a way that the head looks downwards and the convex dorsal surface of the body backwards and the discrete circular facets on the lateral aspect of the base will determine the side to which the bone belongs.

Fifth metacarpal bone. The most distinguishing feature of the fifth metacarpal bone is the *presence of a non-articular tubercle on the medial aspect of its base* which gives insertion to the *extensor carpi ulnaris muscle*. The facet on the proximal surface articulates with the hamate bone. The strip-like facet on the lateral aspect of the base articulates with the fourth metacarpal bone. The medial surface of the shaft gives insertion to the *opponens digiti minimi*. The volar aspect of the lateral surface of the shaft gives origin to *fourth palmar interosseous* while its dorsal aspect gives origin to medial or ulnar head of the *fourth dorsal interosseous muscle*.

Side determination. Hold the bone in such a way that its head looks downwards, the convex dorsal surface backwards and the tubercle on the medial aspect of the base will determine the side opposite to the bone or the articular facet on the lateral aspect of the base will determine the side to which the bone belongs.

THE PHALANGES OF THE HAND

General features. The phalanges are fourteen in number, two for the thumb finger and three for each of the other fingers. Each phalanx consists of a *base* or *proximal end*, a *distal end*, and an intervening portion, the *shaft*, which tapers from base to the distal end. The dorsal surface of the shaft is smooth and convex, the volar surface is flattened from side to side and is gently concave from above downwards.

The *base* or proximal end *of the proximal phalanx presents an oval articular facet* which articulates with the head of the metacarpal bone. Its *distal end presents a pulley-shaped articular surface* which articulates with the base of the middle phalanx.

The *base of the middle phalanx presents two small concave facets separated by a smooth* ridge. Its *distal end presents a pulley-shaped articular surface* which articulates with the base of the distal phalanx.

The *base of the distal phalanx has two small concave articular facets separated from each other by a smooth ridge*. Its *distal end forms a non-articular tapering end*. On the palmar surface of its distal end, there is a horse-shoe-shaped tubercle for the attachment of the pulp of the finger.

Particular features. The *proximal phalanx* of the index finger receives insertion of the first dorsal interosseous on the radial side of its base while the second palmar interosseous is inserted on the medial aspect of its base. The proximal phalanx of the middle finger receives insertion of the second and third dorsal interossei on the radial and ulnar side of its base respectively. No palmar interosseous is attached to this bone. The proximal phalanx of the ring finger receives insertion of the third palmar interosseous on the radial side of its base while the fourth dorsal interosseous is inserted on its ulnar side. The dorsal aspect of the proximal phalanx of the index, middle and ring fingers receives insertion of the extensor digitorum. The radial aspect of the proximal phalanx of the medial four fingers receives insertion of the corresponding lumbrical muscle.

The *middle phalanx* receives insertion of the *flexor digitorum superficialis* (*sublimis*) on either side of the volar aspect of its base. The dorsal aspect of the base receives insertion of the lumbricals and the interossei muscles through the extensor expansion.

The volar aspect of the base of the *distal phalanx* gives insertion to *flexor digitorum profundus*. Its dorsal aspect receives insertion of the lumbricals and interossei muscles through the extensor expansion.

Phalanges of the thumb finger. The lateral aspect of the base of the proximal phalanx receives insertion of the *abductor pollicis brevis*, the *flexor pollicis brevis* and the *laterl part of the oblique head of adductor pollicis*; its medial aspect receives insertion of the *adductor pollicis* (transverse head and the rest of the oblique head) and the *first palmar interosseous muscles.* The dorsal aspect of the base receives insertion of the *extensor pollicis brevis.*

The distal phalanx receives insertion of the *flexor pollicis longus* in the volar aspect of its base. The dorsal aspect of its base receives insertion of the *extensor pollicis longus.*

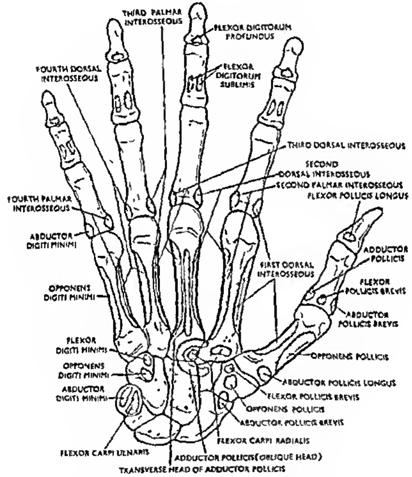


Fig. 308. The anterior view of the skeleton of the right hand showing attachments.

Phalanges of the little finger. The medial aspect of the base of the proximal phalanx gives insertion to *abductor* and *flexor digiti minimi.* Its lateral aspect receives insertion of the *fourth palmar interosseous muscle* and the *fourth lumbrical muscle.* The remaining two phalanges have similar attachments like that of the other fingers except the dorsal interosseous muscle.

Structures of the bones of the hand. CARPAL BONES. All the carpal bones are composed of a thin layer of compact bone externally which forms their outer shell and a network of fine trabeculae internally.

Metacarpal bones and phalanges. They are long bones in miniature form and have the same structures as the long bones; compared to their sizes the

compact bone surrounding the meduallary cavity is definitely thicker particularly over the dorsal regions of the phalanges. The nutrient canals from second to the

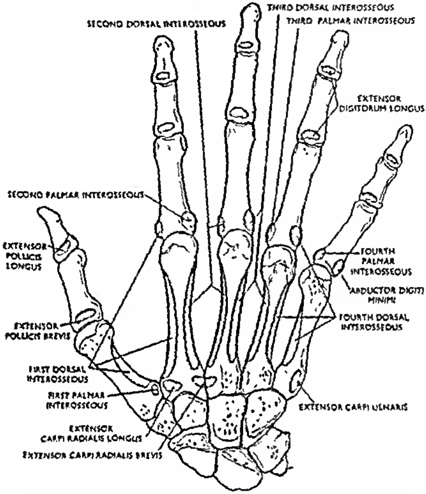


Fig. 309. The posterior view of the skeleton of the right hand showing attachments.

fifth metacarpals are directed towards their bases and in the first metacarpal it is directed towards its head. There are usually two nutrient arteries in each phalanx which pass through the nutrient canals which are directed towards the head. The nutrient foramina of the metacarpal bones and the phalanges are situated on their ventral aspects.

Ossification. Carpal Bones. Each of the carpal bones ossifies from one centre of ossification which appears after birth. At birth they are cartilaginous and after the onset of ossification the process is usually completed between twentieth and twenty-fifth years.

In the male the ossification starts in the capitate and hamate at first year, in the triquetral at third year, in the lunate at fourth year, in the scaphoid at fifth year, in the trapezium and trapezoid between fifth and sixth years and in the pisiform between tenth and twelfth years.

In the females the ossification usually starts about one year earlier than the males.

Metacarpal Bones. Each metacarpal bone ossifies from two centers, one primary centre for the body and one secondary centre for its epiphysial end. The medial four metacarpal bones have their epiphyses at their distal ends or in otherwords the head forms the epiphysis in the medial four metacarpal bones whereas in the first metacarpal the base forms its epiphysis.

The primary centre for the body appears at 9th week of foetal life and the secondary centre for the epiphyses of the metacarpal bones appears at 3rd year. Each epiphysis unites with the diaphysis between 17th and 19th years.

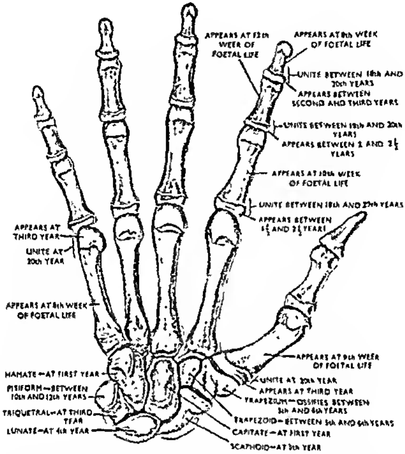


Fig. 310. The ossification of the bones of the hand.

Phalanges. Each phalanx ossifies from one primary centre for the body which appears between eighth and twelfth weeks of foetal life, and one secondary centre for the base which appears at 3rd year. The epiphysis unites with the diaphysis between 17th and 19th years.

THE HIP BONE

The hip bones or the os coxae are two in number and together form the greater part of the pelvic girdle. Each is a large irregular bone, constricted in the middle but expanded both above and below. On its lateral aspect it presents a large socket, the *acetabulum* for the receptions of the head of the femur. The acetabular wall is deficient below to form a notch known as the acetabular notch; below this there is a large aperture, the *obturator foramen* which in the recent state is covered by the obturator membrane and obturator muscle.

Each hip bone consists of three parts—*ilium*, *ischium* and *os pubis* and during early life they all remain distinct from each other by an intervening y-shaped cartilage at the bottom of the acetabulum but later on, in adult life, this cartilage undergoes ossification and the three segments of the hip bone become osseously continuous with one another. The ilium is the upper expanded portion which projects upwards

from the acetabulum; the pubis projects downwards, forwards and medially above the obturator foramen while the ischium projects downwards and backwards from the acetabulum.

Side determination. Hold the bone in such a way that the ilium projects upwards, the pubis is directed forwards and medially above the obturator foramen, the acetabular notch looks vertically downwards or the anterior superior iliac spine and the pubic crest lie in the same vertical plane and the acetabulum of the hip bone will determine the side to which the bone belongs.

ILIUM

General features. The upper flat and expanded portion of the hip bone constitutes the ilium which projects upwards from the acetabulum. It consists of *upper* and *lower ends, anterior, posterior* and *medial borders* and *external* or *gluteal and*

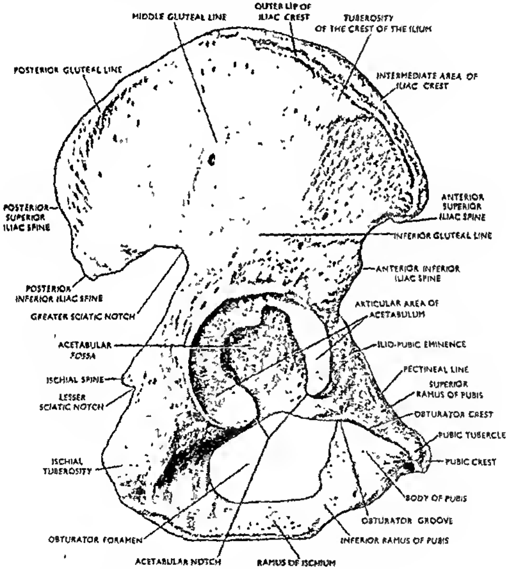


Fig. 311. The right hip bone. External aspect.

internal surfaces. The internal surface is further subdivided into an anterior hollowed portion known as the *iliac fossa* and a posterior portion known as the *sacro-pelvic surface.*

The upper end of the ilium is of considerable length and thickness and is known as the *iliac crest*. *Anteriorly* it forms a bony projection known as the *anterior superior iliac spine* while the *posterior superior iliac spine* forms a similar projection, but less prominent, from its posterior end. The iliac crest is divided into ventral $^2/_3$ and dorsal $^1/_3$ (ventral and dorsal segments). The ventral segment of the iliac crest is divisible into an *outer lip*, an *inner lip* and an *intermediate area*. An outward bony projection from the outer lip about 2 inches behind the anterior superior iliac spine is known as the *tubercle of the crest of the ilium* which corresponds to the level of the fifth lumbar vertebra. The dorsal segment consists of an *outer* and an *inner sloping area*. The general outline of the iliac crest forms an arch and the summit of the convex arch or

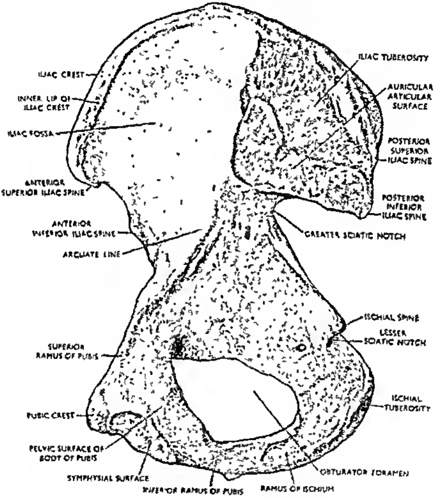


Fig. 312. The right hip bone. Internal aspect.

the highest point of the iliac crest lies a little behind the mid-point of the iliac crest and *corresponds with the upper border of the fourth lumbar vertebra*. Thus the highest point of the iliac crest is an important guide for counting the vertebrae.

N.B. The operation of lumbar puncture is performed through the intervertebral space between the third and the fourth lumbar vertebrae or between the fourth and the fifth lumbar vertebrae and to ascertain this space the highest point of the iliac crest is taken as a guide. If the highest points of the two iliac crests are joined posteriorly by a transverse line this will cross the upper border of the fourth lumbar vertebra opposite to the median plane.

The lower end of the ilium corresponds with the line of fusion with the rest of the bone at the bottom of the acetabulum.

The *anterior border* of the ilium begins in the anterior superior iliac spine and then forming a *notch* the concavity of which is directed forwards and laterally it passes in a bony projection below known as the *anterior inferior iliac spine* and finally it terminates into the acetabular margin.

The *posterior border* begins from the posterior superior iliac spine and forming a short notch merges below in the *posterior inferior iliac spine* from where it runs forwards and then turns backwards and downwards forming a deep notch known as the *greater sciatic notch.* Finally it becomes continuous with the posterior border of the ischium.

The *gluteal surface* is divided into four areas by the *posterior, middle* and *inferior gluteal lines.* The *posterior gluteal line* is the shortest of the three and begins from the iliac crest about 2 inches in front of the posterior superior iliac spine and curving backwards and downwards ends in front of the posterior inferior iliac spine. The *middle gluteal line* is the largest of the three and begins from the middle of the greater sciatic notch and ascending upwards and forwards it ends in the outer lip of the iliac crest just in front of the tubercle of the crest of the ilium. The *inferior gluteal line* begins from the upper part of the anterior inferior iliac spine and curving backwards it ends opposite to the lower part of the greater sciatic notch. Between the acetabular margin and the inferior gluteal line there is a rough grooved area for muscular attachment.

The internal surface is divided into *iliac fossa* and *sacro-pelvic surface.* The *iliac fossa* is a hollowed out smooth area situated on the anterior part of the internal or medial surface and is bounded above by the iliac crest, in front by the anterior border and behind by the medial border. The iliac fossa converges forwards and downwards into a *shallow groove* which is bounded laterally by the anterior inferior iliac spine and medially by a bony prominence known as the *ilio-pubic eminence* which marks the line of fusion between the ilium and the pubis. The *sacro-pelvic surface* is divided into *upper rough, sacral,* and *lower, smooth, pelvic areas.* The sacral area consists of an upper non-articular tuberosity known as the *iliac tuberosity* and a lower articular area known as the *auricular surface* because it resembles the pinna of the ear. The pelvic area is further subdivided into *upper* and *lower pelvic areas.* The upper pelvic area lies immediately below the auricular surface and is marked by a rough groove known as the *pre-auricular sulcus* which is more well marked in case of female. The lower pelvic area is smooth and is continuous with the pelvic surface of the body of the ischium.

Particular features

Iliac crest. The outer lip of the ventral segment gives attachment to the *fascia lata* including the *ilio-tibial tract* throughout its whole length. The outer lip in front of the tuberosity gives origin to *tensor fasciae latae.* Above the tensor fasciae latae the anterior half of the outer lip gives insertion to *obliquus externus abdominis* while the posterior one-third gives origin to *latissimus dorsi.* A small interval between the origin of the latter and the insertion of the former forms the base of the lumbar triangle. The inner lip of the ventral segment gives origin to *transversus abdominis* in its anterior two-thirds and to *quadratus lumborum* in its posterior one-third. The *anterior* and *middle layers of the lumbar fascia* are attached medial and lateral to the quadratus lumborum respectively. Below the transversus abdominis and quadratus lumborum the inner lip gives attachment to the *fascia iliaca* and the *iliacus muscle.* The intermediate area of the ventral segment gives origin to *obliquus internus abdominis.*

The outer sloping area of the dorsal segment gives origin to *gluteus maximus* and attachment to *fascia lata;* the inner sloping area gives origin to *sacrospinalis muscle.*

The anterior superior iliac spine gives attachment to the lateral end of the *inguinal ligament,* and origin to *sartorius* which extends to the notch below it. Its lateral margin gives attachment (origin) to *tensor fasciae latae* and fascia lata while its medial margin gives attachment to *transversus abdominis* (origin) and *fascia iliaca.* The notch below the anterior superior iliac spine *gives exit to the lateral cutaneous nerve of the thigh.* The anterior inferior iliac spine is divided into upper and lower areas;

The upper two-thirds of the iliac fossa give origin to *iliacus muscle.* The nutrient foramen at the postero-inferior part of the iliac fossa transmits the nutrient branch *of the ilio-lumbar artery.* The *shallow groove* between the anterior inferior iliac spine and the ilio-pubic eminence transmits the *tendon of the iliacus and psoas major muscles* and the *femoral vessels and nerves.* The iliacus tendon lies laterally and the psoas medially; the femoral artery (the external iliac artery becomes the femoral from the level of the inguinal ligament) lies in front of the psoas tendon. The femoral nerve lies in between the iliacus and psoas. The *iliac fossa on the right side* is in relation to the following structures from behind forwards.

(1) Branches of the ilio-lumbar artery.
(2) Iliacus muscle.
(3) Lateral cutaneous nerve of the thigh.
(4) Fascia iliaca.
(5) Iliac lymph glands.
(6) Caecum, vermiform appendix, beginning of the ascending colon and the terminal portion of the ilium.

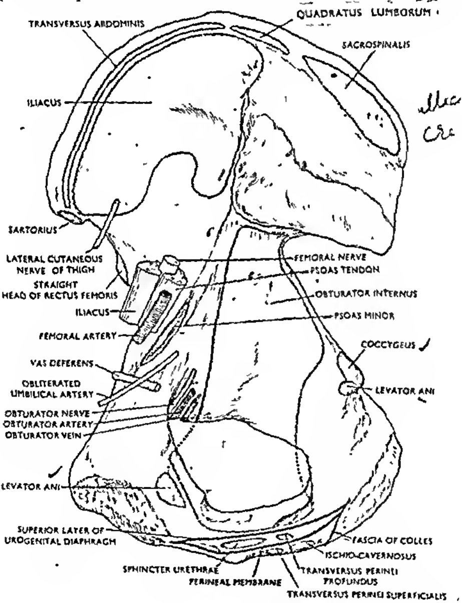


Fig. 314. The internal aspect of right hip bone showing attachments and relations.

The *left iliac fossa* is in relation to all the above structures except those under item 6 and instead it contains the terminal portion of the descending colon.

The sacro-pelvic surface is separated from the iliac fossa by the sharp medial margin which is continuous below with a rounded line known as the *arcuate line;* the middle of the arcuate line gives insertion to *psoas minor muscle;* the medial margin gives attachment to anterior *sacro-iliac ligament.* The iliac tuberosity gives attachment to *ilio-lumbar, posterior sacro-iliac* and *interosseous sacro-iliac ligaments* from before backwards. The auricular surface articulates with the similar surface on the lateral mass of the sacrum. Its anterior and inferior margins together with the pre-auricular sulcus gives attachment to *anterior sacro-iliac ligament.* The lower pelvic surface gives origin to some fibres of the *obturator internus muscle.*

The area behind the posterior gluteal line gives origin to *gluteus maximus* above and attachment to *sacrotuberous ligament* below. The area between the posterior and middle gluteal lines gives origin to *gluteus medius;* the area between the middle and inferior gluteal lines gives origin to *gluteus minimus.* The groove in between the inferior gluteal line and the acetabular margin gives origin to the *reflected head of the rectus femoris muscle.*

ISCHIUM

General features. The ischium forms the postero-inferior part of the hip bone and consists of a *body* and a *ramus.*

The *body* of the ischium consists of *femoral, dorsal* and *pelvic surfaces, upper* and *lower ends* and *anterior, posterior* and *lateral borders.*

The upper end of the body of the ischium is fused with the ilium and pubis at the acetabulum. The lower end forms the most dependent part of the hip bone and corresponds with the lower part of the ischial tuberosity. The *anterior border* forms the posterior margin of the obturator foramen. The *posterior border* is continuous above with the posterior border of the ilium where it forms the anterior boundary of the greater sciatic notch. Below the greater sciatic notch it forms a bony projection known as the *ischial spine* and below that it is curved to form the *lesser sciatic notch.* The lateral border is indistinct above and well marked below where it separates the femoral surface from the ischial tuberosity.

The *femoral surface* is directed downwards, forwards and laterally and lies in between the lateral and the anterior borders of the body. The *dorsal surface* is divisible into *upper, smooth, convex area* and *lower, rough area* known as the *ischial tuberosity.* The ischial tuberosity is separated from the upper area by a groove. The ischial tuberosity is divided into an *upper quadrilateral area* and a *lower triangular area* by a transverse ridge. The upper quadrilateral area is further subdivided into an *upper lateral area* and a *lower medial area* by an oblique ridge; the lower triangular area is divided into lateral and medial areas by a ridge. The pelvic surface is smooth and is separated from the ischial tuberosity by a prominent margin.

The ramus of the ischium begins as a continuation of the body and passes upwards, forwards and medially to join the inferior ramus of the pubis. It consists of *anterior* or *external* and *posterior* or *pelvic surfaces* and *upper and lower borders.* The anterior surface is directed towards the thigh and is continuous with the anterior surface of the inferior ramus of the pubis. The posterior surface is divided into pelvic and perineal areas by an indistinct ridge. Its upper margin forms the margin of the obturator foramen while its lower margin forms the lateral boundary of the urogenital triangle.

Particular features. The lower part of the femoral surface adjoining the obturator foramen gives origin to some fibres of the *obturator externus.* Just in front of the lateral margin a short strip of the femoral surface gives origin to *quadratus femoris.* The notch between the upper end of the ischial tuberosity and the acetabular margin lodges the *tendon of the obturator externus* as it passes backwards to be inserted into the femur. The upper part of the lateral margin and the adjoining portion of the acetabular margin gives attachment to *ischio-femoral ligament.*

The pelvic surface of the body close to the obturator foramen gives origin to *obturator internus* and the rest of this surface is covered by the same muscle together with its covering fascia and forms in this situation the *lateral wall of the ischio-rectal fossa*. The internal pudendal vessels, and the pudendal nerve, which divides into dorsal nerve of the penis or clitoris and perineal nerve, lie in a fascial canal known as the *pudendal canal* in this situation. The pudendal canal is an inter-fascial canal formed by the obturator fascia laterally and the deep fascia of the ischio-rectal fossa or the fascia lunata medially.

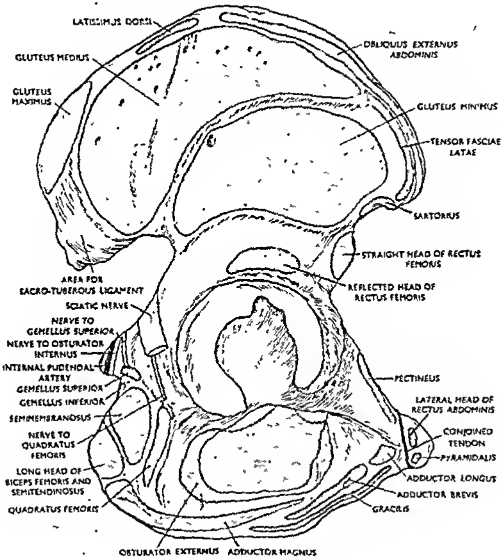


Fig. 315. The external aspect of right hip bone showing attachments and relations.

The upper part of the *dorsal surface* where it is smooth and convex is covered by the piriformis muscle. The shallow groove between the upper and lower parts of the dorsal surface lodges the *common tendon of obturator internus and the gemellus superior et inferior*.

The lower part of the dorsal surface is formed by the ischial tuberosity. The lateral part of the upper quadrilateral area gives origin to *semimembranosus* while the lower area gives origin to the *common tendon of the long head of the biceps femoris and the semitendinosus*. The lateral area of the lower triangular part gives origin to *adductor magnus* while the medial area is covered by fibro-fatty tissue on which there lies the

ischial bursa of the gluteus maximus and its medial margin gives attachment to *sacrotuberous ligament* with its falciform process.

The *ischial spine* gives attachment to *sacrospinous ligament* by its tip. Its pelvic surface gives origin to *levator ani* in front and *coccygeus* behind. The lower border of the ischial spine gives origin to *gemellus superior*. The dorsal or external surface of the ischial spine is crossed by the *internal pudendal vessels*, and the *nerve to the obturator internus* which lie on its lateral side. The pudendal nerve lies medial to the internal pudendal vessels over the sacrospinous ligament.

The *lesser sciatic notch* lies below the ischial spine and is converted into lesser sciatic foramen by the sacrotuberous and sacrospinous ligaments. It transmits the *tendon of the obturator internus, internal pudendal vessels, pudendal nerve* and *the nerve to the obturator internus*. Except the tendon of the obturator internus, all the structures enter into the pelvis again. The lower part of the lesser sciatic notch immediately above the ischial tuberosity gives origin to *gemellus inferior*. The nerve to the quadratus femoris intervenes between the common tendon of obturator internus and gemellus superior et inferior, and the surface of the bone in this situation.

The anterior surface of the ramus of the ischium gives origin to *obturator externus* laterally (adjoining the obturator foramen) and to *adductor magnus* medially in most of its extent but close to the inferior ramus of the pubis the *gracilis and adductor brevis* extend to this surface from the inferior ramus of the pubis and from medial to the lateral side the order is gracilis, adductor brevis, adductor magnus and obturator externus. The posterior surface of the ramus of the ischium is divided into pelvic and perineal areas. The pelvic area gives origin to *obturator internus* while the upper part of the perineal area gives origin to *sphincter urethrae* and the *transversus perinei profundus* laterally and to the *crus penis* or *clitoris* medially. The lower part of the perineal area gives origin to ischio-cavernosus and *transversus perinei superficialis* which are situated on a plane medial to sphincter urethrae and in line with crus penis or clitoris. The upper border of the ramus gives attachment to *obturator membrane* while its lower border gives attachment to *fascia lata and fascia of Colles*. The *perineal membrane* which extends from the inferior ramus of the pubis intervenes between the *transversus perinei superficialis et ischio-cavernosus* and the *sphincter urethrae et transversus perinei profundus* and is attached to an indistinct ridge. The ridge separating the perineal from the pelvic area gives attachment to the superior layer of the urogenital diaphragm.

THE PUBIS

General features. The pubis occupies the anterior part of the hip bone and articulates with the fellow of its opposite side to form the symphysis pubis. It consists of a *body*, a *superior ramus* and an *inferior ramus*.

The *body* is flattened from before backwards and connects the superior ramus with the inferior ramus. It lies medial to the obturator foramen and consists of *anterior, posterior* and *medial* or *symphyseal surfaces*. The *anterior surface* is rough above and smooth below and is directed downwards, forwards and laterally. The *posterior surface* is smooth and forms the anterior boundary of the true pelvis. The *symphyseal* or *medial* surface is rough and elongated and articulates with the fellow of its opposite side to form the symphysis pubis. The upper border of the body is thick and strong and is known as the *pubic crest*. The pubic crest ends laterally into a tubercle known as the *pubic tubercle*.

The *superior ramus* of the body lies above the obturator foramen and passes upwards and backwards and laterally to join in the acetabulum. It consists of an *antero-superior border* or *obturator crest*, a *postero-superior border* or the *pectineal line* and an *inferior border*, and a *pectineal*, an *obturator* and a *pelvic surface*. The *antero-superior border* or the *obturator crest* begins from the anterior part of the pubic tubercle and passes laterally to end in the anterior part of the acetabulum. The *pectineal line* is sharp and prominent and begins from the posterior part of the pubic tubercle and passing laterally and backwards becomes continuous with the arcuate line. The *inferior border* forms the upper boundary of the obturator foramen and is rough and prominent

medially. The *pectineal surface* lies in between the obturator crest anteriorly and the pectineal line posteriorly and is bounded laterally by the ilio-pubic eminence and medially by the pubic tubercle. The *obturator surface* is grooved to form the *obturator groove* and lies in between the obturator crest and the inferior border. The *pelvic surface* is continuous with the pelvic surface of the body and lies in between the pectineal line and the inferior border.

The *inferior ramus* lies medial to the obturator foramen and begins from the lower part of the body, and descending downwards, backwards and laterally it becomes continuous with the ramus of the ischium. It consists of *anterior* and *posterior surfaces* and *lateral* and *anterior borders*. The *anterior surface* is directed downwards, forwards and laterally and is bounded laterally by the lateral margin which forms the medial boundary of the obturator foramen. Medially this surface is bounded by the anterior border which separates this surface from the posterior surface. The *posterior* or *inner surface* is continuous with the posterior surface of the ramus of the ischium below and with the posterior surface of the body of the pubis above. Two indistinct ridges subdivide this surface into three areas—medial, intermediate and lateral.

Particular features. The pubic tubercle gives attachments to the medial end of the *inguinal ligament*, the *upper loop of the cremaster* muscle and the *anterior layer of the rectus sheath*. It lies in the floor of the subcutaneous inguinal ring and is crossed by the spermatic cord or the round ligament of the uterus. The lateral part of the *pubic crest* gives origin to the *lateral head of the rectus abdominis* while its anterior part gives origin to the *pyramidalis muscle* and the *conjoined tendon* is attached to it antero-lateral to both these muscles. The medial head of the rectus abdominis has no bony origin but it arises from the condensed mass of fibro-areolar tissue in front of the symphysis pubis and in its course upwards it crosses the medial part of the pubic crest.

The *anterior surface* of the body immediately below the angle formed by the junction of the pubic tubercle and the pubic crest gives origin to the *rounded tendon of the adductor longus muscle*. Medial to this the rough area on the anterior surface gives attachment to the *anterior pubic ligament*. Below the attachments of the anterior pubic ligament and the adductor longus the rest of the anterior surface gives origin to *gracilis, adductor brevis* and the *obturator externus* from medial to the lateral side. The *posterior surface* of the body in its lower half gives attachment to *medial pubo-prostatic ligament, levator ani muscle* (origin), *parietal layer of pelvic fascia* and *obturator internus* (origin) from medial to lateral side. The upper part of this surface is related to the urinary bladder and is separated from the same by the retropubic pad of fat. The *symphyseal* or *medial surface* is covered by a layer of hyaline cartilage and articulates with the fellow of its opposite side by the intervention of a fibro-cartilage and forms the symphysis pubis which is a *secondary cartilaginous joint*.

The medial part of the pectineal line, from before backwards, gives attachment to the *pectineal part* of the *inguinal ligament, conjoined tendon* and the *transversalis fascia* and *fascia iliaca*. Its lateral part gives attachment to the *pectineal ligament* and the *pectineal fascia*. The obturator crest together with the ilio-pubic eminence gives attachment to the *pubo-capsular* or *pubo-femoral ligament*. The inferior border gives attachment to the *obturator membrane*. The pectineal surface in its medial part gives origin to the *pectineus muscle*. The obturator groove transmits the *obturator vessels* and *nerves* and from above downwards are the *obturator nerve, obturator artery* and the *obturator vein*. As the pelvic fascia bridges across the lower part of the obturator groove, *the above structures pass to the obturator groove without piercing the fascia*.

The pelvic surface of the superior ramus is crossed by the *obliterated umbilical artery* and the *vas deferens* in the male, and the *round ligament of the uterus* and the *obliterated umbilical artery* in the female and is covered by the parietal peritoneum.

The anterior surface of the *inferior ramus*, gives origin to *gracilis, adductor brevis, adductor magnus* (to the lower part of this surface only) and *obturator externus* in order from medial to lateral side. The posterior surface of the inferior ramus is divided into lateral, intermediate and medial areas by two indistinct ridges. The ridge separating the medial from the intermediate area gives attachment to the *perineal membrane*

(inferior layer of the urogenital diaphragm) while the ridge separating the later: from the intermediate area gives attachment to the *superior layer of the urogenit diaphragm.* The medial area gives origin to the *crus of the penis* or *clitoris*, the inter mediate area is in relation with the internal pudendal vessels and the dorsal nerve of the penis or clitoris and gives origin to *sphincter urethrae* and the lateral area gives origin to *obturator internus.* The lateral margin gives attachment to the *obturator membrane* while the anterior or medial margin gives attachment to *fascia lata* and to *the membranous layer of the superficial fascia of the perineum* (fascia of Colles). To summarise, from lateral to the medial margin, the structures attached are the *obturator membrane, obturator internus muscle, superior layer of the urogenital diaphragm, sphincter urethrae, perineal membrane, crus of the penis* or *clitoris, fascia of Colles* and the *fascia lata.*

Acetabulum. The acetabulum forms a cup-shaped cavity into which the spheroidal head of the femur articulates. It is covered everywhere by articular cartilage except at its bottom where it forms a rough depression known as the *acetabular fossa* which in the recent state is filled up by some pad of fat covered by synovial membrane. The acetabular margin is deficient inferiorly so as to leave a gap known

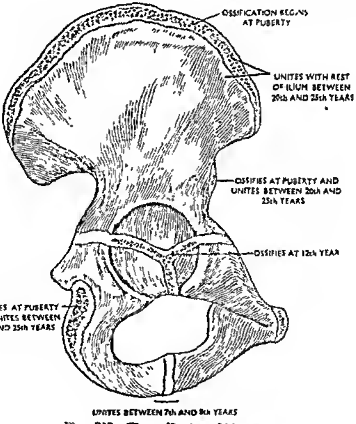


Fig. 316. The ossification of hip bone.

as the *acetabular notch.* The two ends of the notch give attachment to the *transverse acetabular ligament* which bridges over this gap. The margins of the acetabular fossa close to the acetabular notch give attachment to the *limbs of the ligament of the head of the femur* (Ligamentum teres femoris). The tunnel formed under the transverse acetabular ligament transmits the *articular branches from the obturator vessels and nerves.* The ischium, pubis and the ilium remain separated from one another during embryonic life and up to certain stage after birth by a Y-shaped cartilage but

during adult life they all fuse together and become osseously continuous with one another. The pubis constitutes the upper and anterior fifth of the articular surface of the acetabulum, the ischium forms the posterior and lower two-fifths of the articular surface, and the acetabular fossa, and the remainder of the acetabulum is formed by the ilium.

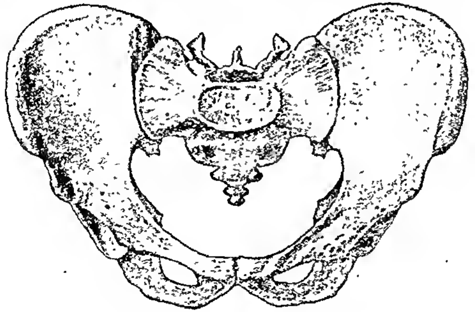
Ossification. Each hip bone ossifies from eight centres—*three primary* and *five secondary* and the centres of ossification appear as follows :

(1) Primary centre for the ilium ..	Eighth or ninth week of foetal life.
(2) Primary centre for the body of the ischium.	Third month of foetal life.
(3) Primary centre for the superior ramus of the body.	Between fourth and fifth months of the foetal life.
(1) Secondary centre for the iliac crest.	At puberty.
(2) Secondary centre for the anterior inferior iliac spine.	At puberty.
(3) Secondary centres for the inferior ramus of the pubis and the ramus of the ischium.	Ossification begins soon after birth and they are united together by the eighth year.
(4) Secondary centre for the ischial tuberosity.	At puberty.
(5) Secondary centre for the bottom of the acetabulum.	By the twelfth year.

All the secondary centres completely unite with one another by the twenty-fifth year.

THE PELVIS

The lower division of the abdominal cavity resembles a basin (pelvis=a basin) in its form and is called the *pelvis* and the bony framework that surrounds it is also called the pelvis but to be more precise it should better be called the *bony pelvis*. In an articulated skeleton the two hip bones together with the sacrum and coccyx form a girdle of bone, the bony pelvis, or the pelvic girde which provides a wide base for the support of the trunk and transmits the weight of the body to the ground through the lower limbs on which it stands.



;. 317. A female pelvis showing its inlet.

Anatomical position. In erect posture the bony pelvis maintains an inclined position in which the anterior superior iliac spines and the pubic tubercles are in the same vertical plane and the upper border of the symphysis pubis lies on a same level with the tip of the coccyx. Thus in anatomical position the dorsal wall of the bony pelvis looks mostly upwards while its ventral wall faces downwards.

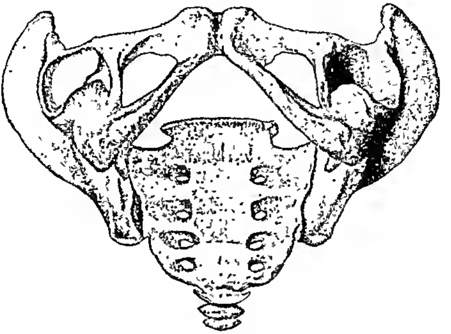


Fig. 318. A female pelvis showing its outlet.

Sub-division of the pelvis. The pelvis is sub-divided into two parts, false or greater pelvis and true or lesser pelvis, by the *brim of the pelvis.* The brim of the pelvis is formed by a pair of arched lines, the *arcuate lines* which meet together both in front and behind opposite the median plane. The arcuate line of each side can be divisible into sacral, iliac and pubic parts. The sacral part is formed by the sacral promontory and the anterior border of the ala sacralis; the iliac part is formed by the lower half of the medial border of the ilium; the pubic part of the arcuate line is formed by the pectineal line, pubic crest and the upper border of the symphysis pubis.

False pelvis. The false pelvis lies above the pelvic brim and forms the lower part of the abdomen proper. It has no encircling bony wall and is limited by the iliac fossae only. Clinically it is of some value in indicating the size of the true pelvis.

True pelvis. It lies below the pelvic brim and is bounded by a ring of bony wall. Anteriorly it is bounded by the pelvic surface of the symphysis pubis and the body of the pubis, posteriorly it is bounded by the sacrum and coccyx; on either side it is bounded by the pelvic surface of the ischio-pubic rami, the body of the ischium and the lower part of the sacro-pelvic surface of the ilium. Its posterior wall is much longer (5"-6") and follows the sacro-coccygeal curvature whereas its anterior wall is too short measureing only about 1 to 2 inches.

The true pelvis is continuous above with the abdomen at the pelvic brim, and below, it is communicated to the exterior. Thus the true pelvis consists of an *inlet*, an *outlet* and a *cavity*.

The inlet of the true pelvis is formed by the pelvic brim which is either heart-shaped or round and is bounded by the arcuate lines which have alrea-

quadrate tubercle gives insertion to the *quadratus femrois* muscle which extends downwards on to the shaft for a short distance.

The CAPSULAR LIGAMENT is attached anteriorly to the trochanteric line, posteriorly to the neck about ½ inch above the trochanteric crest, superiorly to the neck above the trochanteric fossa and the root of the greater trochanter and inferiorly it is attached to the neck immediately above the lesser trochanter.

The LINEA ASPERA or the posterior border of the SHAFT forms a conspicuous thick crest opposite to the middle-third of the shaft and is marked by density of the compact substances opposite this level and compensates for the weakness caused by the anterior convexity of the bone. The lateral lip of the linea aspera up to the upper half of the body and including the lateral margin of the gluteal tuberosity gives origin to the vastus lateralis. The medial lip of the linea aspera including the upper two-thirds of the medial supracondylar line gives origin to the *vastus medialis* and below this level the vastus medialis takes its origin from the tendon of adductor magnus (see the accompanying diagram). The *adductor magnus* is inserted into the whole length of the linea aspera and extends upwards along the medial margin of the gluteal tuberosity and downwards along the medial supracondylar line to the adductor tubercle. In between the vastus medialis and adductor magnus the medial intermuscular septum is attached throughout the whole length and the *adductor brevis* is inserted above and the *abductor longus* is inserted below. In between the adductor magnus and the vastus lateralis the lateral intermuscular septum is attached throughout the whole length and the *gluteus maximus* is inserted above and the *short head of the biceps femoris* arises from below. The nutrient foramen in the lower part of the linea aspera transmits the nutrient artery which passes towards the upper end of the bone.

The *anterior* and *lateral* surfaces in the upper three-fourths of the shaft give origin to the *vastus intermedius*. The lower one-fourth of the lateral surface is covered by the vastus intermedius muscle. From the upper part of the lower-fourth of the anterior surface the *articularis genu muscle* arises by a few slips and the rest is occupied by the suprapatellar bursa. *The medial surface does not give attachment to any muscle but is covered by the vastus medialis muscle.* The *upper posterior surface* gives attachment of the following muscles in order from lateral to the medial side—*gluteus maximus, adductor magnus, adductor brevis, prectineus, iliacus* and the *vastus medialis*. The *popliteal surface* presents a low rounded tubercle in its lower part medially which gives origin to the *medial head of the gastrocnemius*. Another less prominent tubercle on the lower part laterally gives origin to *plantaris muscle*. The lateral supracondylar line in the upper two-thirds gives origin to the *short head of the biceps femoris* and in its lower-third gives origin to some fibres of the *plantaris* and the *lateral head of the gastrocnemius*, and to the *lateral intermuscular septum* throughout the whole length. The medial supracondylar line in its upper two-thirds gives origin to *vastus medialis* and throughout its whole length to the *adductor magnus* except where it is pierced by the femoral artery, and to the medial *intermuscular septum*.

The condyles of the lower end of the femur articulate inferiorly with the condyles of the tibia by the intervention of the semilunar cartilages, and with the patella anteriorly. The tibial articular surfaces of the two condyles are not similar. That of lateral condyle is wider passes straight backwards while that of the medial condyle is longer, narrower and extends more upwards posteriorly. Moreover the medial condyle is gently curved with the convexity medialwards and descends for 0.5 cm. more than the lateral one. This accounts for more excursion and rotatory movement of the medial condyle than the lateral one during flexion and extension of the knee joint. The medial epicondyle gives attachment to the *medial ligament* of the knee joint. The adductor tubercle gives insertion to the tendon of the *adductor magnus*. The epiphysial cartilage of the lower end lies opposite to this level and so it forms an important landmark for the same. The lateral epicondyle gives attachment to the *lateral ligament* of the knee joint. The anterior part of the popliteal groove gives origin to the *popliteus muscle* while its posterior part lodges the tendon of the same muscle when the knee joint is fully flexed. The tendon of origin of the

popliteus is intracapsular but extrasynovial. The postero-superior part of the lateral epicondyle presents a groove or a muscular impression for the origin of the lateral head of the *gastrocnemius*. The intercondylar line gives attachment to the

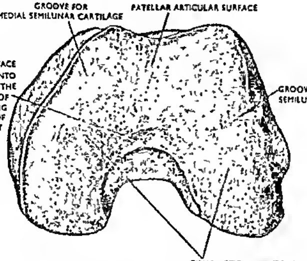


Fig. 329. The inferior view of the lower end of left femur.

capsular ligament and its lateral part also gives attachment to the *oblique popliteal ligament*. The medial surface of the lateral condyle bears an impression which gives attachement to the upper end of the *anterior cruciate ligament*. A similar impression on the lateral surface of the medial condyle gives attachment to the upper end of the *posterior cruciate ligament*. Both the cruciate ligaments are intracapsular but extrasynovial.

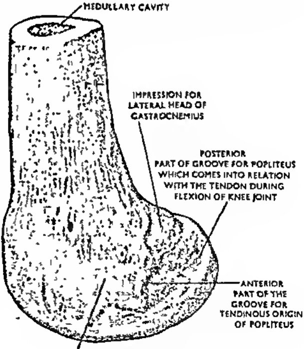


Fig. 330. The lateral view of the lower end of left femur.

The capsular ligament in the lower end. Anteriorly it is deficient and the synovial protrusion through this forms the suprapatellar bursa; posteriorly it is attached to the intercondylar line. Laterally it is attached to the lateral surface of the lateral condyle above the groove for the popliteus muscle. Medially it is attached to the medial surface of the medial condyle just above the articular surface.

Ossification. It ossifies from five centres—*one primary centre* for the body and *four secondary centres*, i.e., one for the greater trochanter, one for the lesser trochanter, one for the head and one for the lower end.

The primary centre for the body appears during the seventh week of intrauterine life and extends towards its end. The secondary centre for the head appears

during the first year, for the greater trochanter during the fourth year and for the lesser trochanter between 12 and 14 years. The secondary centre for the lower end appears during the *ninth month of intrauterine life* and this is a deviation from the laws of ossification. All the secondary centres unite with the shaft independently after puberty. The lower end unites with the diaphysis between eighteenth and twentieth years.

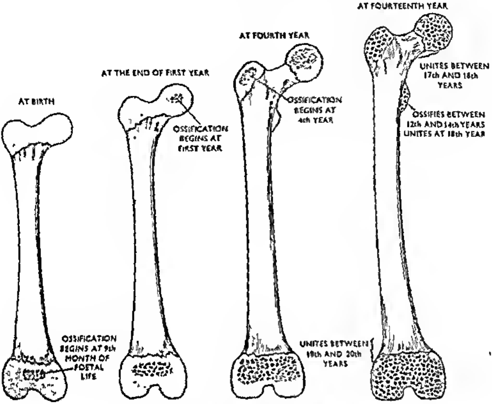


Fig. 331. The stages of ossification of the femur.

Structure of the femur. In a vertical section through the femur it is found that it consists of a medullary cavity within and a compact layer outside. The compact substance is thickest opposite to the middle-third of the bone but away from this it gradually becomes thinner and thinner and ultimately opposite to the ends it forms a thin compact outline within which there lies a bulk of spongy substance. In the upper end opposite to the head, neck and the trochanters, running within the spongy substance there are series of thin compact lamellae of bones which converge to the centre of the bone to a central wedge which links up the head and the body. A thin vertical compact bone extends upwards into the neck from the region of the linea aspera and is known as the *calcar femorale.* The medullary cavity is only well marked opposite to the middle-third of the shaft and towards the ends its place is taken up by spongy substance.

N.B. The secondary centre of ossification for the lower end of the femur begins to appear just before birth. When the viability of an infant comes into question, in case of infanticide, and if under X-ray the lower end of the femur shows signs of ossification, it is certain that the infant was viable and this forms the *medico-legal importance of the lower end of the femur.*

Alteration in the anatomical angles of the femur leads to certain deformity which affects greatly the function of the limb. The normal neck-shaft vertical angle is 127° and the forward neck-shaft angle is 14·01°. When both these angles are reduced a condition known as *Coxa Vara* occurs in which the movement of abduction is very much restricted. The greater trochanter is raised up and there

surface gives attachment to the ligamentum patellae. The upper half to upper two-thirds of the medial margin receives insertion of the vastus medialis including the distal-most horizontal fleshy fibres of the vastus medialis and the rest give attachment to the medial patellar retinacula. Its lateral margin gives insertion to the tendinous fibres of vastus lateralis in its upper part only adjoining the base where it presents an impression and most of the fibres of vastus lateralis are inserted to this impression (Grant). The rest of the lateral border gives attachment to the lateral patellar retinacula. The anterior surface is rough and presents innumerable vascular foramina and a series of vertical ridges. In the recent state it is covered by an expansion from the common tendon of quadriceps femoris which is prolonged downwards to blend with the ligamentum patellae distally. The lower part of this surface is separated from the skin by the subcutaneous prepatellar bursa.

The posterior surface is mostly articular and partly non-articular. The non-articular area, which lies on its lower part, can be divisible into upper and lower parts. The upper part gives attachment to the infrapatellar pad of fat while its lower part together with the apex gives attachment to the ligamentum patellae.

The lateral facet on the posterior surface articulates with the lateral condyle of the femur while the medial facet articulates with the medial condyle of the femur. The vertical articular ridge fits into the groove on the patellar surface of the femur.

Ossification. The patella ossifies from a single secondary centre which appears during the third year of life. The ossification is completed at puberty.

N.B. According to recent views the quadriceps femoris muscle is not inserted into the patella but it is inserted into the tibia through a tendon which passes over and round the patella.

Formerly it was believed that the patella was an essential element of the knee joint and that by pulley mechanism it augments the muscle force of the quadriceps femoris muscle. But recent works done by Brooke have shown that it is not an essential element of the knee joint and its removal by excision does not reduce the power of the knee joint but it actually increases it.

Fracture of the patella may take place either by direct violence or by indirect violence in which powerful contraction of the quadriceps femoris against resistance, as in sudden contraction of the quadriceps in semi-flexed or flexed knee, comes into the mechanism of fracture.

Stability of patella. During contraction of the quadriceps femoris, which tends to displace the patella laterally, its stability is maintained by the *tension of the medial patellar retinaculum,* contraction of muscular fibres of vastus medialis attached to the medial margin of patella and by the presence of the *forward bulging of the lateral condyle of the femur.*

Dislocation of patella is very rare, but when it occurs, it is usually displaced laterally because the femur is set obliquely on the tibia which is vertical making an angle which is open towards the lateral side. Due to this, the oblique pull of the quadriceps femoris (oblique from above downwards and medially) to the vertical attachment of the ligamentum patellae to the tibial tuberosity straighten out the angulation formed between the attachment of the quadriceps femoris to the patella and the ligamentum patellae to the tibia and as a result, the patella tends to be displaced over the front of the lateral condyle of the femur. *Normally this defect in the muscular mechanism is aptly compensated for by the forward projection of the lateral condyle of the femur and by the lower attachment of the vastus medialis to the patella and by the tension of the medial patellar retinaculum.* Due to forward projection of the lateral condyle the lateral bank of the trochlear articular surface of the lower end of the femur becomes more raised and as a result the patella finds it a disadvantage to ride over it. Moreover the vastus medialis being attached to the upper $^2/_3$ of the medial margin of the patella, during contraction of the quadriceps femoris the former (vastus medialis) tends to drag it medially and thus preventing lateral displacement. Therefore, it appears that dislocation of patella can occur in those cases where the vastus medialis

is weak either congenitally or by trauma or by paralysis and where due to congenital defect the lateral femoral condyle is poorly developed.

THE TIBIA

The tibia is the medial bone of the leg and excepting the femur it is the longest bone in the body. It consists of two ends and an intervening portion known as the body or shaft. Its upper end is broad and expanded while its lower end is small and less substantial. From the *medial aspect* of the lower end a bony process descends downwards below the rest of the bone and is known as the *medial malleolus*. The body is prismoid in shape and gradually tapers from above downwards. Its *anterior border* is sharp and prominent and below it inclines medially to end above the medial malleolus.

Side determination. Hold the bone in such a way that its broad upper end looks upwards, the sharp anterior border of the shaft looks forwards and the medial malleolus will determine the side opposite to the bone.

General features. The *upper* end of the tibia is broader transversely than antero-posteriorly and consists of *lateral* and *medial condyles*, a *tubercle* and a rough uneven area in between the two condyles superiorly known as the *intercondylar area*. Anteriorly the two condyles are continuous with each other by a convex triangular area, the apex of which is directed downwards and corresponds to the tubercle of the tibia. The lateral margin of the traingular area forms a prominent oblique ridge which separates this area from the lateral surface of the body. Its medial margin is less prominent and separates this area from the medial surface of the body. Posteriorly both the condyles overhang the upper part of the posterior surface of the shaft and the two condyles are separated from each other by a short, thick concave border.

The lateral condyle is smaller than the medial condyle and projects backwards so as to overhang the posterior surface of the shaft especially at its posterolateral part. A circular facet, known as the *fibular facet*, is present on the inferior aspect of its overhanging posterolateral part and articulates with the head of the fibula. Superiorly the lateral condyle presents a smooth articular surface which is *circular* in general outline and is gently hollowed out in its centre. Its medial part is prolonged on to the lateral aspect of the lateral intercondylar tubercle. The lateral condyle articulates with the lateral condyle of the femur.

The medial condyle is larger than the lateral condyle but does not project so much backwards as the lateral condyle. Superiorly its articular surface is *oval* in outline and extends over the medial aspect of the medial intercondylar tubercle. On the posterior aspect of the medial condyle immediately below its articular surface there is a rough horizontal groove for muscular attachments.

The tubercle of the tibia is a prominent bony eminence situated at the upper end of the anterior border and corresponds to the apex of the triangular area in front of the two condyles. It consists of an upper smooth portion and a lower rough portion.

The intercondylar area is the rough space between the superior articular surfaces of the two condyles. It gradually widens both in front and behind but is narrow at the centre where it forms an irregular eminence known as the *intercondylar eminence*. The intercondylar eminence is broken into two tubercles, the *lateral* and the *medial intercondylar tubercles* which are separated from each other by a narrow groove.

The shaft or body of the tibia is prismoidal in shape and is triangular on transverse section. It gradually narrows from above downwards up to the junction of the middle with the lower-third of the bone and then gradually expands to end into the lower end. It consists of *anterior*, *lateral* or *interosseous* and *medial borders* and *lateral*, *medial* and *posterior surfaces*.

The *anterior border* is popularly known as the *'shin'* of the tibia and is sharp and prominent in its upper two-thirds but rounded and less distinct below. It begins from the lower part of the tubercle of the tibia and ends below at the anterior margin of the medial malleolus. At first it runs downwards and medially, then downwards and laterally and finally it turns medially to end in the medial malleolus; in other words it is sinuously curved. The *interosseous* or the lateral border begins from the *antero-inferior part of the* fibular facet and descends vertically downwards up to the lower end where it divides into two limbs to enclose a triangular depressed area on the lateral aspect of its lower end and forms the *fibular notch.* The *medial border* begins from the anterior end of the groove on the back of the medial condyle of the tibia and running vertically downwards it ends in the posterior border of the medial malleolus. Its upper and lower parts are less distinct but its middle part is sharp and prominent.

The *medial surface* lies in between the medial and the anterior borders and is subcutaneous throughout its extent. In front of the upper part of the medial border this surface presents a rough area which measures about 2 inches in length and 2/5 inch in breadth. The *lateral surface* lies in between the anterior and interosseous borders and is gently hollowed out in its upper two-thirds. Its lower one-third is slightly convex and expanded and encroaches to the anterior aspect because of the medial deviation of the anterior border in this situation. The *posterior surface* lies in between the interosseous and the medial borders and is wider above and narrow below. An oblique ridge the *soleal line,* runs downwards and medially from in front of the fibular facet and ends in the medial

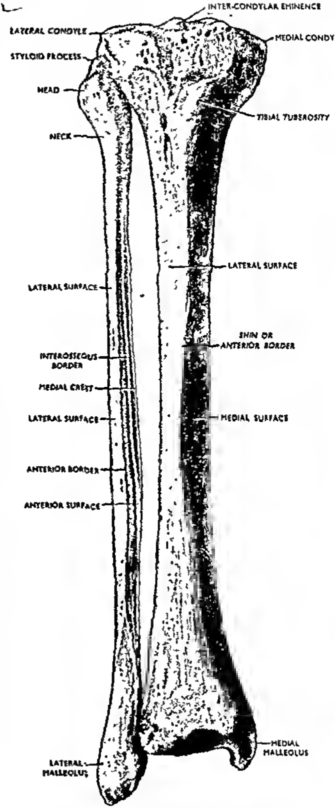


Fig. 333. The bones of the right leg as seen from the front.

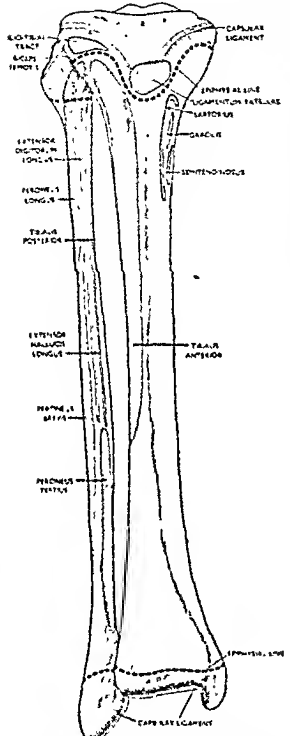


Fig. 334 The attachments on the bones of the right leg as seen from the front.

border opposite to the junction of the upper with the middle-third of the bone. The soleal line subdivides the posterior surface into upper and lower areas. The lower area is further subdivided into medial and lateral areas by a vertical ridge.

The lower end of the tibia is broad and expanded and consists of *anterior, posterior, lateral, medial* and *inferior surfaces* and the *medial malleolus.*

The *anterior surface* of the lower end is gently convex and is separated from its inferior surface by a narrow transverse groove. The *posterior surface* is directed backwards and is separated from the inferior surface by a sharp margin At its medial part this surface presents a vertical groove which is continued downwards on to the posterior aspect of the medial malleolus. The *lateral surface* of the lower end forms a wide notch, the *fibular notch of the tibia* which is tri- ... shape. Both anteriorly and posteriorly it is bounded by sharp margins which converge above in the interosseous border to form its apex. The *medial surface is* convex and subcutaneous and is prolonged downwards into a process known as the medial malleolus. The *inferior surface* is smooth and articular and articulates with the superior surface of the body of the talus. Medially its articular surface is continuous with the articular surface on the lateral aspect of the medial malleolus.

The *medial malleolus* is a short, thick bony projection from the medial aspect of the lower end ond consists of *medial, lateral, anterior* aod *posterior surfaces* and an *inferior border.* Its medial surface is convex and subcutaneous. Its lateral surface presents a comma-shaped articular facet which articulates with the similar facet oo the medial aspect of the body of the talus. Both the anterior and posterior surfaces are marked by a shallow groove. Its inferior or lower margin is pointed both in front and behind but is marked by a depressed impression in the middle for the attachment of the deep part of the deltoid ligament.

Particular features. The articular surface of the medial condyle is hollowed

out centrally but is flattened at its periphery where it is in contact with the medial semilunar cartilage. It is oval in shape and is broader antero-posteriorly. Its sharp peripheral margin gives attachment to the *coronary ligament*. The groove on the back of the medial condyle gives insertion to *semimembranosus*. The upper margin of the groove gives attachment to the *capsular ligament of the knee joint* while its lower margin gives attachment to the *short posterior fibres of the medial ligament of the knee joint*. The superior articular surface of the lateral condyle is circular in outline and its peripheral portion is in contact with the lateral semilunar cartilage. Anterolaterally this

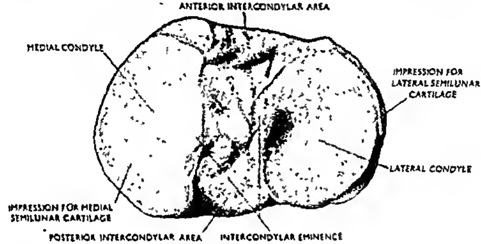


Fig. 335. The top view of right tibia.

surface is separated from the rest of the bone by a sharp margin which gives attachment to the *coronary ligament* but posteriorly it is separated from the posterior aspect of the body by a rounded margin which comes into relation with the *tendon of the popliteus*. A *bursa* usually intervenes between this tendon and the bone. The fibular facet articulates with the head of the fibula and its circumferential margin gives attachment to the *capsular ligament for the superior tibio-fibular joint*. The lateral surface of the lateral condyle just in front of the fibular facet occasionally gives origin to some fibres of the *extensor digitorum longus and peroneus longus*, the former being anterior to the latter and insertion to some fibres of the *biceps femoris*. The triangular, convex anterior surface formed by both the condyles is in relation to the deep *infrapatellar bursa*. The sharp margin separating it from the lateral surface of the body gives attachment to the *iliotibial tract* and the *deep fascia of the leg*. The intercondylar area gives attachment to the following structures in order from before backwards—*Anterior end of the medial semilunar cartilage, lower end of the anterior cruciate ligament, anterior end of the lateral semilunar cartilage* (in front of the intercondylar eminence), *posterior end of the lateral semilunar cartilage, posterior end of the medial semilunar cartilage* and *the lower end of the*

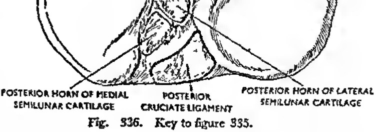


Fig. 336. Key to figure 335.

posterior cruciate ligament (behind the intercondylar eminence). The ridge on the posterior aspect of the intercondylar area gives attachment to the *capsular ligament of the* knee joint. The upper smooth part of the *tubercle of the tibia* gives attachment to the *ligamentum patellae* while its lower part is in contact with the *subcutaneous infrapatellar bursa.*

The *anterior border* of the shaft is subcutaneous and gives attachment to the *deep fascia of the leg* (fascia cruris) and immediately above the medial malleolus this border gives attachment to the *superior extensor retinaculum.* Immediately above the medial malleolus the anterior border is crossed by the long saphenous vein and the saphenous nerve. The *interosseous border* gives attachment to the *interosseous membrane* which begins from the antero-inferior part of the fibular facet and ends below at the apex of the fibular notch where it is continuous with the inferior interosseous tibio-fibular ligament. Superiorly, immediately below the fibular facet the interosseous membrane is deficient and through this gap in the upper end of the interosseous membrane the anterior tibial artery enters the anterior compartment of the leg. The *medial border* gives attachment to the following structures in order from above downwards—(a) *Medial ligament of the knee joint,* (b) *Fascia covering the popliteus,* (c) *Soleus* with its covering fascia and (d) the deep fascia of the leg.

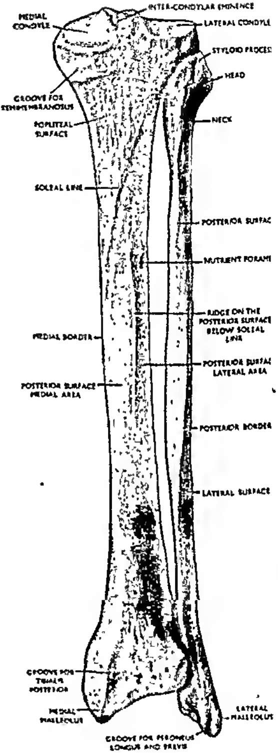


Fig. 337. The bones of the right leg. Seen from behind.

anterior border and is in relation to the *tendon of the tibialis anterior, extensor hallucis longus, anterior tibial vessels, anterior tibial nerve, tendon of the extensor digitorum longus* and the *peroneus tertius.*

The *posterior surface* above the soleal line forms part of the popliteal fossa and gives insertion to the *popliteus muscle.* The soleal line ends above in a tubercle which gives attachment to the medial end of the tendinous arch of the soleus and below this it gives origin to the *soleus* and attachment to the *fascia covering the soleus and the popliteus* and *the deep fascia of the leg.* The lateral area of the lower part of the posterior surface gives origin to the *tibialis posterior* in its upper three-fourths while the medial area gives origin to the *flexor digitorum longus.* The *lower one-fourth of the posterior surface does not give any attachments* but is occupied by the tendons of the tibialis posterior and the flexor digitorum longus. The tendon of the flexor digitorum longus lies at first on the medial side of the tibialis posterior and then crosses superficial to it to the lateral side.

The *anterior surface* of the *lower end* is in relation to the same structures that come in relation to the lower part of the lateral surface of the shaft. The groove separating the anterior from the inferior surface gives attachment *to the capsular ligament of the ankle joint* and the ridge above the groove gives attachment to the *anterior ligament of the ankle joint.*

The sharp margin that separates the posterior from the inferior surface gives attachment to the *capsular ligament* and to the *posterior ligament of the ankle joint.* From medial to the lateral side the *posterior surface* of the lower end is in relation to the *tendons of the tibialis posterior, flexor digitorum longus, posterior tibial vessels, posterior tibial nerve* and the *tendon of the flexor hallucis longus.* The tendon of the tibialis posterior is contained in the groove behind medial malleolus and the medial part of the posterior surface. The sharp margin of the groove gives attachment to the *flexor retinaculum of the leg.*

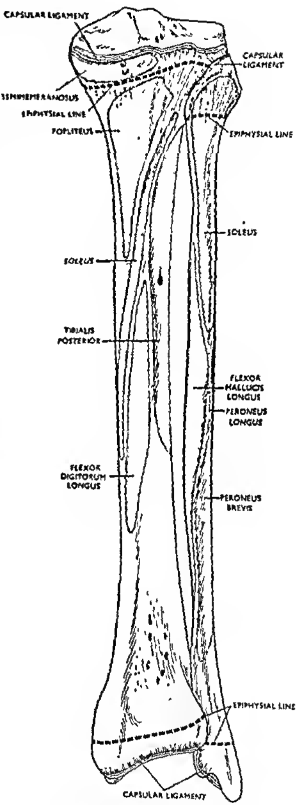


Fig. 338. The attachments on the bones of the right leg as seen from behind.

The *lateral surface* is formed by the fibular notch and articulates with the lowe end of the fibula. Its anterior and posterior margins give attachment to the *anterio* and *posterior inferior tibio-fibular ligaments* respectively. The grooved area gives attach- ment to the *interosseous tibio-fibular ligament* and firmly connects the tibia and th fibula together and this articulation is known as the inferior tibio-fibular syndesmosis

The *medial surface* is subcutaneous and is continuous with the medial surface of th medial malleolus.

The *inferior surface* is articular and articulates with the superior surface of th body of the talus. It is continuous with the comma-shaped facet on the latera aspect of the medial malleolus.

The anterior, inferior and the posterior margins of the medial malleolus close t the articular surface give attachment to the *capsular ligament of the ankle joint*. The depressed impression on its lower border gives attachment to the *deep part of the deltoid ligament* while more superficially the medial malleolus gives attachment to the *superficial part of the deltoid ligament*. The grooves on the anterior and posterior aspects of the medial malleolus transmit the tendons of the *tibialis anterior* and *tibialis posterior* respectively. The comma-shaped facet on the lateral aspect articulates with the similar facet on the medial surface of the body of the talus.

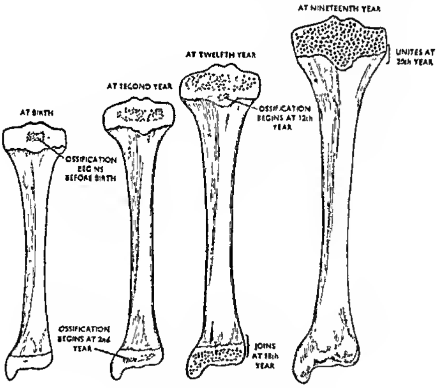


Fig. 339. The stages of ossification of the tibia.

Ossification. The tibia ossifies from one primary centre and two secondary centres. The primary centre for the body appears during the seventh week of foetal life. The secondary centre for the upper end appears shortly after birth and extends forwards and downwards as a tongue-shaped process to form the tubercle. The secondary centre for the lower end appears during the second year of life. The lower epiphysis unites with the body during the eighteenth year while the upper epiphysis unites with the body during the twentieth year.

summit of the arch and transmits the body weight along the limbs of the arches. Like the carpal bones the tarsal bones are also placed in two rows—proximal and distal but the arrangement is not regular as in case of the former. The calcaneum and the talus form the bones of the proximal row and the cuneiform bones form the bones of the distal row. The navicular is interposed between the talus and the cuneiform bones and the cuboid is placed laterally in front of the calcaneum.

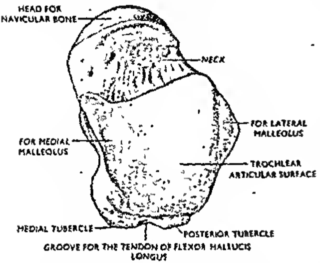


Fig. 343. The right talus Seen from above.

THE TALUS

The talus is the principal connecting bone between the foot and the bones of the leg and takes an important part in the formation of the ankle joint. It consists of *a head, a neck* and *a body.* The head is more or less rounded and is covered by articular cartilage and is directed forwards, medially and downwards. The constriction immediately behind the head is the neck and just succeeding the neck is the expanded body, the superior *surface of which* presents a convex articular surface. On the lateral side of the body is a large triangular facet and on the medial side is a comma-shaped facet.

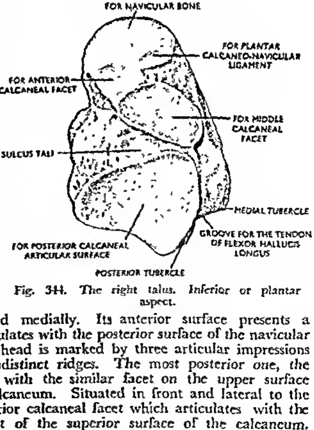


Fig. 344. The right talus. Inferior or plantar aspect.

Identification of sides. Hold the bone in such a way that its rounded head looks forward, downward and slightly medially, the superior convex surface of the body looks upwards and the large triangular facet on the lateral surface of the body will determine the side to which the bone belongs.

General features. The head of the talus is directed forwards and slightly downwards and medially. Its anterior surface presents a convex articular surface which articulates with the posterior surface of the navicular bone. The inferior surface of the head is marked by three articular impressions separated from one another by indistinct ridges. The most posterior one, the middle calcaneal facet, articulates with the similar facet on the upper surface of the sustentaculum tali of the calcaneum. Situated in front and lateral to the middle calcaneal facet is the anterior calcaneal facet which articulates with the similar facet on the anterior part of the superior surface of the calcaneum. Situated medial to the calcaneal facets is a rounded impression which is in direct contact with the spring ligament or the plantar calcaneo-navicular ligament.

The neck. The neck is the constricted portion that connects the head and the body together. The long axis of the neck is directed downwards, forwards and media-

lly and it joins the body at an angle which measures about 150°. This angle is much less (130°-140°) in case of the infants and is responsible for the inverted foot in the growing infants. Its upper surface is rough for ligamentous attachments. Its inferior surface presents a groove, the *sulcus tali* which with a similar groove on the upper surface of the calcaneum forms a tunnel, the *sinus tarsi*.

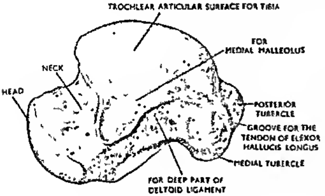


Fig. 345. The right talus Medial aspect

The body. The body of the talus is broad and expanded and is cuboidal in shape. It consists of superior, inferior, lateral, medial and posterior surfaces. The *superior surface* is the trochlear articular surface which is convex from before backwards and slightly concave from side to side and articulates with the lower end of the tibia to form the ankle joint. It is broader in front than behind. Its medial margin is straight and salient and is continuous with the articular facet on the medial surface. Its lateral margin is less prominent and traced backwards it gradually inclines to the medial side and at its posterior end there is a roughened triangular impression which comes in contact with the inferior transverse tibio-fibular ligament in extreme dorsiflexion of the ankle joint, thus this mechanism is a safeguard against dorsal displacement of the talus; and moreover during dorsiflexion, the broader anterior part of the trochlea is also engaged in the tibio-fibular mortise. The broader anterior part of the trochlea has another advantage. During walking, everytime the foot touches the ground, the tibio-fibular mortise tends to slip forward but the broader anterior part of the trochlea nicely engages the mortise and thus forward movement of the leg bones over the talus is prevented. Along the lateral border the superior articular surface is continuous with the articular area on the lateral surface of the bone. The *lateral surface* is almost fully occupied by a triangular articular facet the apex of which is directed downwards. It articulates with the lateral malleolus. The pointed non-articular portion below the apex of the triangular articular facet constitutes the *lateral tubercle* of the bone. The *medial surface* presents at its upper part a comma-shaped articular surface for the medial malleolus and a rough depressed area below for ligamentous attachment. The *posterior surface* is rough and is marked by a shallow groove for the passage of the flexor hallucis longus tendon. This groove divides the lower part of this surface into *medial* and *posterior tubercles*. The *posterior tubercle* lies on the lateral side while the *medial tubercle* lies on the medial side of the groove. The *inferior surface* presents a deep oval concave articular surface for articulation with the convex oval facet on the intermediate part of the superior surface of the calcaneum.

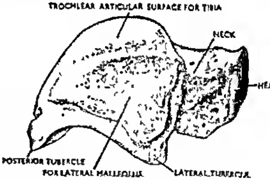


Fig. 346. The right talus. Lateral aspect.

been described. Due to inclined position of the pelvis, the plane of the inlet is an oblique plane which meets the horizontal at an angle of about 60° (inclination of the inlet).

The axis of the inlet. It corresponds to a line which cuts the centre of the plane of the inlet at right angles; the line, if continued both upwards and downwards, would pass through the umbilicus and the tip of the coccyx respectively.

Diameters of the inlet. ANTERO-POSTERIOR DIAMETER—Three antero-posterior diameters are considered in respect of the inlet of the pelvis and all of them start posteriorly from the middle of the sacral promontory; anteriorly they are measured in relation to the symphysis pubis which forms the anterior wall of the bony pelvis.

Anatomical conjugate, True conjugate or *conjugate vera.* This is an anterio-posterior diameter of the inlet of the pelvis which is measured from the middle of the sacral promontory to the upper border of the symphysis pubis. It measures about 4" in the males and 4½ inches in the females,

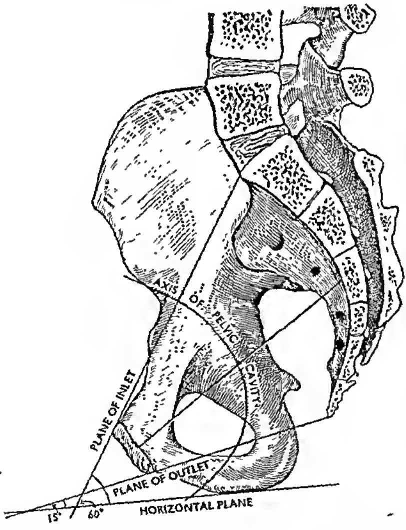


Fig. 319. A mid-sagittal section of pelvis showing the planes, axes and inclination.

Obstetrical conjugate. This is also an antero-posterior diameter of the inlet which is a great concern to an obstetrician and is measured from the middle of the sacral promontory to the inner surface of the symphysis pubis a little below its upper margin (nearest point in the middle line).

Diagonal conjugate. This antero-posterior diameter of the inlet is measured from the middle of the sacral promontory to the lower border of the symphysis pubis.

TRANSVERSE DIAMETER. The transverse diameter of the intlet is a side-to-side diameter which extends from the mid-point of the arcuate line of one side to the same point on the opposite side. It is about 5" in the males and 5¼" in the females. This line is nearer to the sacrum than the symphysis pubis and it does not pass through the centre; it is of less practical value clinically.

OBLIQUE DIAMETER. This diameter extends from the ilio-pubic eminence of one side to the middle of the sacro-iliac articulation of the opposite side. It measures about 4¾" in the males and 5" in the females.

For obvious reasons true conjugate diameter in the females is a great concern to an obstetrician. Its measurement varies from race to race as well as in the living and the dried pelves of the same race. The following is a chart which shows racial variations of the conjugate (true) diameter (measurements taken on dried pelves) published by various authors.

Authors	Races	Conjugate diameter in Cm.
P. Das P. C. Mahalanobis N. K. Roy Choudhuri	Bengali (Indian)	9 68
N. L. Pan	Bengali (Indian)	10 10
Koganei and Osawa	Japanese	10 7
Martin	Malays	11·5
Martin	Negro	10 1
Emmons	American Indian	10 68
Garson	European Australian Andamanese	10 6 10 8 9 9
Martin	American	11·7
Martin	Australian aborigines	11·4
Martin	German	10 7
Shordania	Russian	10 8 (Mean)

The OUTLET of the true pelvis (*Anatomical outlet*) corresponds to its lower aperture and is roughly diamond-shaped. It is bounded in front by the sub-pubic angle; behind by the tip of the coccyx; on either side by the ischio-pubic rami, ischial tuberosities, ischial spines, sacrotuberous and sacrospinous ligaments and the sides of the sacrum and coccyx. *Obstetrical outlet* or *the narrow pelvic plane* is an imaginary plane bounded in front by the lower border of the symphysis pubis, laterally by the tips of the ischial spines, and posteriorly by the lower border of the last sacral vertebra. This is of greater importance to an obstetrician than the anatomical outlet which is not fixed (due to moveable coccyx) and does not lie in a same plane. The *plane of the outlet* makes an angle varying between 10 and 16 degrees with the horizontal. The *axis of the outlet* is represented by a line which cuts the centre of its plane at right angles; if the line is continued upwards it would strike the sacral promontory. Three diameters are taken into consideration, antero-posterior, transverse and oblique, in respect of the pelvic outlet but for all practical purposes only the antero-posterior and transverse diameters are considered. The *antero-posterior diameter* is measured from the tip of the coccyx to the lower border of the symbysis pubis; this diameter is variable due to mobility of the coccyx, particularly in the

females in living condition. It measures about 3" in males and 4" in females. The *transverse diameter* is measured from one ischial tuberosity to the other. It measures 3" in males and 4" inches in females. The *oblique diameter* which is of less practical value is measured from the junction of sacrotuberous and sacrospinous ligaments of one side to the junction of the ischio-pubic rami of the opposite side.

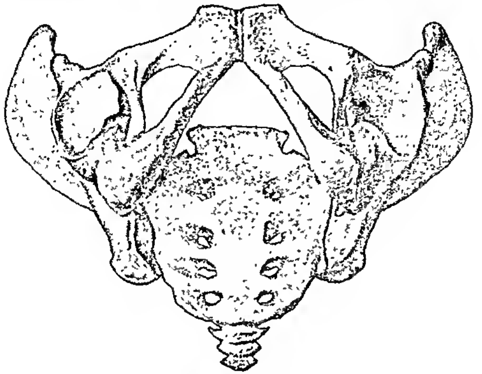


Fig. 320. A male pelvis showing its outlet.

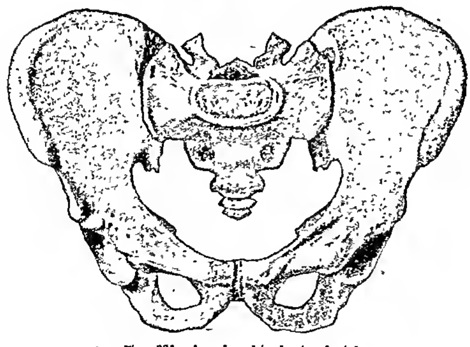


Fig. 321. A male pelvis showing its inlet.

The *cavity of the true pelvis* is a short, curved tunnel which follows the sacro-coccygeal curvature. Its anterior wall is formed by the back of the symphysis pubis and the body of the pubis; it measures about 1 to 2 inches. The posterior wall is formed by the sacrum and coccyx; this wall is much longer than the anterior wall and measures about five or six inches. The side walls of the pelvic cavity are formed by the lower part of the sacro-pelvic surface of the ilium, ischium, obturator membrane and the ischio-pubic rami and by the sacrotuberous and sacrospinous ligaments. The *axis of the pelvic cavity* corresponds to a line which crosses the centres of the planes between the inlet and the outlet. Roughly it is represented by a curved line which follows the sacro-coccygeal curvature.

Other pelvic measurements. The *external antero-posterior diameter* or *external conjugate* is measured from the tip of the first sacral spine to the anterior margin of the upper border of the symphysis pubis. The *intercristal diameter* is the distance between the outer lips of the two iliac crests where they are widest apart. The *interspinous diameter* is measured between the two anterior superior iliac spines.

Normally these diameters are usually longer in the males than in the females and they also vary individually as well as in different races. The follwoing chart shows the measurements of these diameters in the females in various races published by different authors.

COMPARATIVE PELVIC MEASUREMENTS OF DRIED PELVES OF VARIOUS RACES

Author	Races	Interspinous cm.	Intercristal cm.	Intertrochanteric cm.	Ext. Conj cm.
Shordania	Russian	24·4	26·1	.	19·4
Martin	German	24·8	27·5	.	18·1
Runge	Russian	23	26·5	.	18·2
Koganei & Osawa	Japanese	21·5	.	..	17·8
Do	Aino	22·1	.	..	17·8
Garson	European Australian Andamanese	23·1 19·8 17·2	27·1 24·06 20·7	. .. ..	.. .. ..
Ammons	Am. Indian	22·6	25·7	..	..
P. Das P. C. Mahalanobis N. K. Choudhuri	Bengali	20·8	24·76	27·10	17·45

DIFFERENCES BETWEEN MALE AND FEMALE PELVIS

	Male	Female
Bony features	(*a*) The pelvic bones are heavier and stronger and the muscular impressions are more marked.	(*a*) Bones are lighter and less strong and the muscular impressions are less marked.
Sub-pubic angle	The sub-pubic angle is smaller and varies from 58° to 60°.	The sub-pubic angle is wider and varies from 80° to 90°.
The nature of the pelvic cavity	The pelvic cavity is funnel-shaped and looks like a larger section of a smaller cone (outlet is m u c h smaller than the inlet).	It is more or less tubular in character and looks like a smaller section of a larger cone (inlet and outlet almost equal).
Pelvic measurements	All diameters are comparatively smaller (inlet, outlet and pelvic cavity).	All diameters are comparatively larger.

DIFFERENCES BETWEEN MALE AND FEMALE PELVIS—(*Contd.*)

	Male	Female
Other measurements	The acetabular diameter equals the distance between the acetabulum and symphysis pubis.	The distance between the acetabulum and the symphysis pubis is one inch more than the acetabular diameter.
Feature pertaining to the external genital organ	The outer margin of the ischio-pubic rami is everted and the area for the crus penis is wider.	The margin of the ischio-pubic rami is less everted and the area for the crus clitoris is narrower.
Obturator foramen	The obturator foramen is larger and oval.	The obturator foramen is smaller and triangular.
The acetabulum	The acetabulum is larger.	The acetabulum is smaller (usually less than 5 cm. in diameter).
The greater sciatic notch	It is narrower and "fish-hook" in appearance.	It is much wider.
Pre-auricular sulcus	It is less marked.	It is very prominent and well marked.
The pubis	The body and the crest of the pubic bone are less wide.	The body and the pubic crest are wider in the female.
Ischial tuberosity	The ischial tuberosity is inverted.	The ischial tuberosity is everted.
The sacrum	(*a*) The articular part of the base is longer than its non-articular part. (*b*) The auricular articular surface extends upto the third sacral vertebra. (*c*) Vertical diameter is greater than the maximum transverse diameter. (*d*) The ventral curvature is gradual. (*e*) Sacral index is lower	(*a*) The non-articular part of the base is longer than its articular part. (*b*) The auricular articular surface extends upto second sacral vertebra (or a little lower). (*c*) Vertical and transverse diameters are almmt equal. (*d*) It is abruptly curved in its lower part. (*e*) Sacral index is higher
Ischium-pubis index*	Below 90	Above 90

Types of the female pelvis. Every female pelvis does not bear the same characteristics but variations are found in many which mainly fall under four main types as ascertained by measurements of the inlet of the pelvis.

(1) *Long pelvis.* In long pelvis the antero-posterior diameter is longer than the transverse diameter.

(2) *Round pelvis.* Under this type the antero-posterior diameter equals the transverse diameter.

(3) *Oval pelvis.* Here the transverse diameter exceeds the antero-posterior diameter by $\frac{1}{2}$ to $1\frac{1}{2}$ inches.

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* The ischium-pubis index is the ratio between the length of the pubis and the length of the ischium and is expressed as $\frac{\text{the length of the pubis} \times 100}{\text{the length of the ischium}}$. In the male it is usually below 90 and in the female it is above 90.

(4) *Flat pelvis.* Here the transverse diameter exceeds the antero-posterior diameter by more than 1½ inches.

Caldwell and Moloy in describing the anatomical variations of the female pelvis on the basis of the shape of the pelvic inlet, sub-divided the female pelves into four main groups as follows:

(1) Gynaecoid pelvis—This is the typical female pelvis with oval pelvic inlet in which the antero-posterior diameter is smaller than the transverse diameter.
(2) Android pelvis—This is a male-type of female pelvis in which the pelvic brim is of triangular shape and the largest transverse diameter is nearer to the sacral promontory, so that, the posterior segment of the inlet is much smaller. The sub-pubic angle and the greater sciatic notches are of male types.
(3) Platypelloid or flat pelvis—This is a flat type of pelvis in which the transverse diameter is much larger than the antero-posterior diameter.

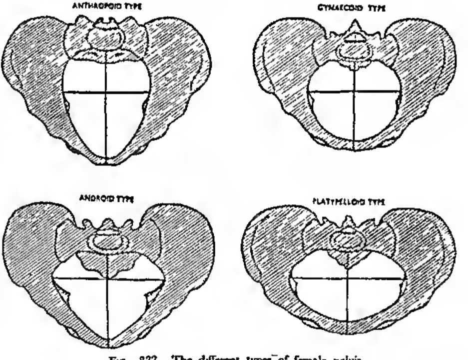


Fig. 322. The different types of female pelvis.

(4) Anthropoid or ape-type of pelvis—This type of pelvis has a much longer antero-posterior diameter and the sacrum is long and narrow. The sub-pubic angle is narrow and the anterior part of the pelvic inlet is not triangular in shape.

THE FEMUR

The femur or the thigh bone is the longest and the strongest bone in the body and consists of a *body* or *shaft* and *two extremities.* The upper extremity consists of a rounded *head*, a *neck*, a *greater trochanter* and a *lesser trochanter.* The head and the neck project *upwards, medially* and *forwards* from the upper part of the body. The body is more or less cylindrical in form and presents a *forward convexity.* The lower end is expanded and consists of two broad condyles, *the lateral and the medial condyles,* which articulate with the condyles of the tibia.

Side determination. Hold the bone in such a way that the head looks upwards and medially, the convex anterior surface of the body looks forwards and the head of the bone will determine the side opposite to the bone.

General features. The HEAD is globular in form and is covered everywhere by articular cartilage except near its centre where it presents a rough depression (*fovea capitis femoris*). It is directed upwards and medially and articulates with the acetabulum of the hip bone to form the hip joint.

The NECK of the femur just succeeds the head and is broad and flattened from before backwards. It links up the head with the body and is oblique in direction. Its upper border is shorter, straighter and almost horizontal in direction while its lower border is longer and oblique and is directed downwards, laterally and backwards. The neck is narrowest in its middle part but wider at its both ends; it is widest at its base where it joins with the upper end of the body. The inclined position of the neck is an added advantage towards better movement. The junction between the neck and the body is marked anteriorly by a roughened ridge known as the *trochanteric line* and posteriorly by a similar ridge known as the *trochanteric crest*. It is pierced by numerous vascular foramina which are more marked on its posterior aspect.

The GREATER TROCHANTER of the femur forms a quadriangular eminence which projects upwards from the junction of the body and the neck. Its postero-superior part projects upwards and medially beyond the level of the neck so as to overhang the latter. It consists of *anterior*, *lateral* and *medial surfaces* and a *superior border*. The anterior surface looks forwards and is rough and irregular. It is separated from the lateral surface by an indistinct ridge. The lateral surface faces lateralwards and is quadrilateral in form. An oblique ridge descends downwards and forwards from its postero-superior angle. Its medial surface presents a deep depression at its postero-inferior part and is known as the *trochanteric fossa*. Above this fossa is a less conspicuous depression for muscular attachment. Its superior border forms a prominent margin and presents a muscular impression anteriorly.

The LESSER TROCHANTER forms a blunt conical eminence at the infero-medial part of the neck and is rough for muscular attachment.

The TROCHANTERIC LINE is a rough oblique ridge placed between the junction of the anterior surface of the neck and the body. It begins above in a small tubercle situated in front of the upper part of the anterior surface of the greater trochanter and runs obliquely downwards and medially to the lower part of the neck where it is continuous with *spiral line* which curves downwards, medially and backwards round the upper part of the body.

The TROCHANTERIC CREST begins from the postero-superior angle of the greater trochanter and ends below in the lesser trochanter. Opposite its mid-point it presents a low rounded elevation known as the *quadrate tubercle*.

THE BODY OR SHAFT of the femur is narrow opposite to its middle part but expands both above and below. It consists of *lateral*, *medial*, and *posterior borders* and *anterior*, *lateral*, *medial*, *upper posterior* and *lower posterior* surfaces. In anatomical position, the body of the femur inclines medially, and this inclination is known as the *angle of obliquity*. The angle of obliquity partly compensates for the inclination of the neck by approximating the weight-bearing articular surfaces of the knee (condyles of the femur and tibia) closer to the centre of gravity. The angle of obliquity of the femur is obtained by the angle formed between the long axis of the femur and the perpendicular line drawn from the horizontal line that passes across the lower surfaces of the femoral condyles; the angle varies between 3° and 15° with an average of 9·56° (Pick, Stock and Anson).

Both the *medial* and the *lateral* borders are ill-defined and rounded. The lateral border separates the anterior from the lateral surface while the medial border separates the anterior from the medial surface. The *posterior border* forms a conspicuous thickened crest opposite to the middle-third of the bone and is known as the LINEA ASPERA. It consists of a *lateral* and a *medial lip* and an *intermediate area*. Both

above and below, the lips of the linea aspera diverge from each other and bind the upper and lower posterior surfaces. Inferiorly the diverging lips of the linea aspera form prominent margins which reach the lateral and the medial condyles of the lower end and are known as the *lateral* and *medial supracondylar lines* respectively. The *lateral supracondylar line* is more prominent and is continuous above with the lateral lip of the linea aspera. The medial *supracondylar line* is less distinct and is deficient in its upper part where it is traversed by the femoral artery in its course from the medial aspect of the thigh to the popliteal fossa. Superiorly the medial lip of the linea aspera is continuous with the spiral line while its lateral lip ascends upwards and laterally to the root of the greater trochanter as a roughened ridge known as the *gluteal tuberosity.* It is often called the *third trochanter* of the femur.

The *anterior surface* is convex in its general outline and is continuous with the medial and lateral surfaces, being separated from them by the ill-defined medial and lateral borders. Its lower part is broader than its upper and middle parts. The *medial surface* lies in between the medial border and the linea aspera and faces backwards and medially while its *lateral surface* intervenes between the linea aspera and the lateral border and faces backwards and laterally. The *upper posterior surface* is bounded laterally by the gluteal tuberosity and medially by the spiral line which is continuous above with the trochanteric line and below with the medial lip of the linea aspera. The *lower posterior surface* is bounded laterally by the lateral supracondylar line and medially by the medial supracondylar line and is known as the *popliteal surface of the femur* and forms the upper part of the floor of the popliteal fossa.

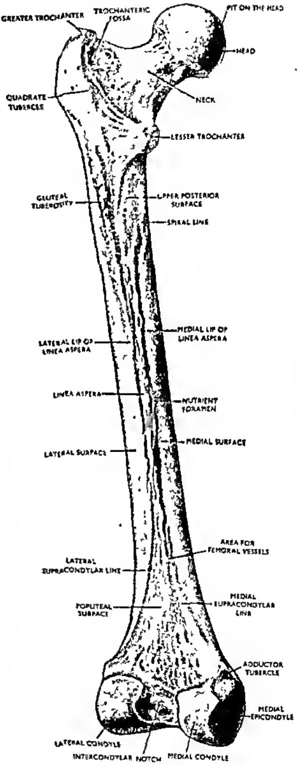


Fig. 323. The left femur viewed from behind.

The LOWER END of the femur is broad and expanded and is divided into *lateral* and

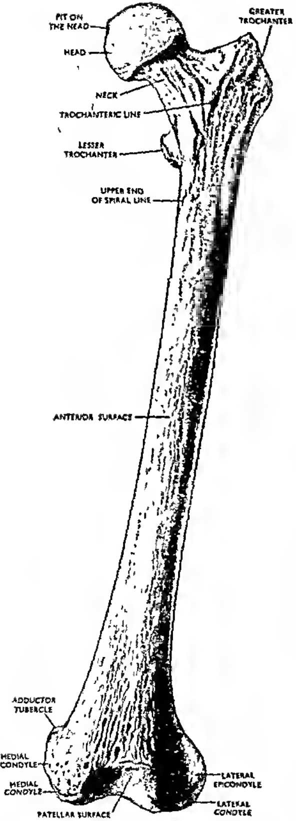


Fig. 324. The left femur viewed from the front.

medial condyles. Each of these condyles is partly articular and partly non-articular. The articular part is covered by hyaline articular cartilage and forms a smooth extensive *articular surface.* The anterior inferior and posterior surfaces of each condyle are covered by the articular surface. Anteriorly the articular surfaces of the two condyles are continuous with each other so as to form a common saddle-shaped articular area known as the *patellar surface* which articulates with the posterior surface of the patella. The patellar articular surface ascends more on the anterior aspect of the lateral condyle than the medial condyle and thus the upper margin of the patellar articular surface is oblique in direction. The patellar articular surface is concave from side to side and is hollowed out antero-posteriorly in its long axis for articulation with the posterior surface of the patella. The patellar articular surface is continuous posteriorly with the tibial articular surface of the corresponding condyle of the femur but a faint groove is usually found in each condyle to form a line of demarcation between the two articulating surfaces. The groove on the lateral condyle is more complete and begins from the anterior part of the intercondylar notch and passes laterally and forwards across the lower surface of the lateral condyle to terminate in a triangular depressed area at the lateral edge of the same. The groove on the medial condyle is restricted to its medial edge only. From the lateral end of the groove on the medial condyle the patellar articular surface extends backwards on the lateral aspect of the medial condyle to form a semiluner area in front of the intercondylar notch. This area articulates with the medial vertical strip of patella during full flexion of knee joint. The posterior and inferior parts of the articular surface of each condyle form the *tibial articular surface* which articulates with the corresponding condyle of the tibia with the intervening semilunar cartilage. The tibial

articular surfaces of the two condyles are separated from each other by the intercondylar notch. Thus the whole femoral articular surface is roughly horse-shoe in appearance. The anterior ends of the two condyles are flush with the anterior surface of the lower part of the shaft while their posterior ends project backwards beyond the level of the popliteal surface and are separated from each other by the *intercondylar notch.* The medial condyle descends to a lower level for about .5 cm. than the lateral condyle and owing to this, when the condyles of the femur articulate with the condyles of the tibia, an angle is formed by their articulation which measures about 170° and is open laterally. This lower descent of the medial condyle partly compensates for the obliquity of the femur.

The *lateral condyle* presents a low rounded elevation on its lateral aspect known as the *lateral epicondyle.* In between this and the articular margin posteriorly there is a groove which is deeper in front than behind. Its medial surface forms the lateral boundary of the intercondylar notch.

The *medial condyle* is more prominent than the lateral condyle and is marked on its medial aspect by a low rounded elevation known as the *medial epicondyle.* Immediately above the medial part of its posterior end it presents a small tubercle known as the *adductor tubercle.* The medial supracondylar line ends in it. The lateral surface of the medial condyle forms the medial boundary of the intercondylar notch.

The *intercondylar notch* separates the two condyles both inferiorly and posteriorly. Posteriorly it is separated from the popliteal surface by transverse ridge known as the *intercondylar line.* Anteriorly it is bounded by the lower border of the patellar surface.

Particular features. The HEAD of the femur is received into the acetabulum of the hip bone to form the hip joint. The depression on the head (*fovea capitis femoris*) gives attachment to the *ligament of the head of the femur* which is intracapsular but extrasynovial. Morphologically the ligament of the head of the femur represents the foetal capsular ligament which has been pinched off by the developing head or perhaps it represents a part of the pectineus.

The NECK of the femur projects markedly medialwards, upwards and slightly forwards from the upper end of the shaft. Due to this medial and upward projection the long axis of the neck makes an angle with the long axis of the shaft, and the angle thus produced is known as the *angle of inclination* which varies considerably

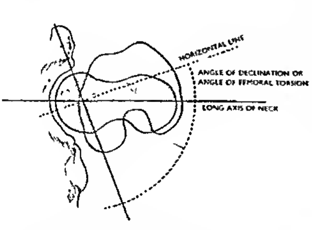


Fig. 325. The angle of declination or torsion of femur.

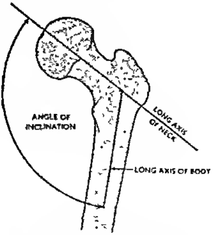


Fig. 326. The angle of inclination of the femur.

with age. In the foetus of about 2.5 months old it is about 141°, in a child of nine months it is about 128°, and in the adult it averages about 127° (Humphry). In females the angle of inclination is slightly smaller than the males. The forward projection of the neck also makes an angle with the shaft

known as the *angle of torsion* or the *angle of declination* which is obtained by the meeting of two lines, one that passes through the long axis of the neck and the other that passes through the centres of the two femoral condyles. The angle of torsion varies considerably from individual to individual and ranges between 1° and 41° with a mean of 14·01° (Pick, Stack and Anson). Anteriorly the neck is completely intracapsular because the latter is attached in front to the trochanteric line. Posteriorly it is partly intracapsular because the capsular ligament is attached to the neck about ½ inch above the trochanteric crest. There may be a deficiency in the line of attachment of the capsular ligament posteriorly, and a synovial protrution through this, forms the bursa for the obturator externus tendon which usually makes a impression on the bone in this part in its course to the trochantic fossa for its insertion. The foramina on the anterior and posterior aspects of the neck transmit the epiphyseal blood vessels. The neck of the femur is lined by the synovial membrane which is thrown into folds as it bridges over the retinacular bands of the capsular ligament. Some of the deeper fibres of the capsular ligament after being attached to their line of attachment in the neck spread over the latter towards the head and form the *retinacular fibres*. These retinacular fibres form three bands, two of which are situated on the anterior aspects of the neck and spread inwards from the upper and lower parts of the trochanteric line. The third retinacular band is placed over the postero-superior part of the neck. The synovial membrane in its course to the neck spreads over these bands.

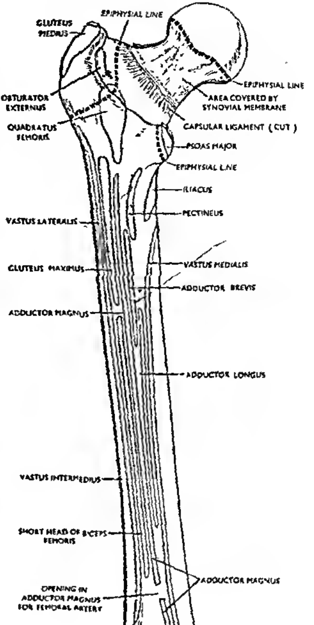


Fig. 327. The posterior view of left femur showing attachments.

The GREATER TROCHANTER of the femur projects upwards and its postero-

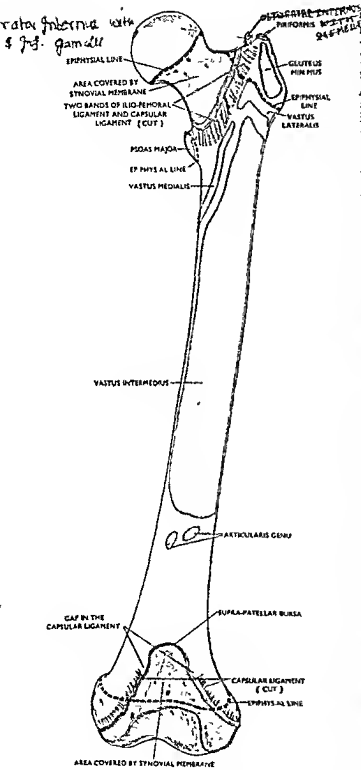


Fig. 328. The anterior view of left femur showing attachments.

superior part overhangs the neck, and it forms a conspicuous bony prominence which can be felt from the skin. Its anterior surface gives insertion to *gluteus minimus*. The oblique ridge on its lateral surface gives insertion to *gluteus medius*. The area in front of it is occupied by a *bursa* for the gluteus medius muscle. The area behind it is covered by the deep fibres of the gluteus maximus being separated by the trochanteric bursa of the same muscle. The trochanteric fossa gives insertion to *obturator externus*. The less conspicuous depression above the trochanteric fossa gives insertion to the common tendon of *obturator internus and gemellus superior et inferior*. The muscular impression on the superior border gives insertion to pyriformis muscle.

The LESSER TROCHANTER of the femur is situated on the infero-medial part of the junction between the neck and the body. Its summit gives insertion to psoas major muscle while the inferomedial part of its base gives insertion to the *iliacus muscle* which extends to the upper posterior surface for a short distance.

The TROCHANTERIC LINE marks the line of junction between the neck and the body anteriorly. It gives origin to two muscles and attachment to two ligaments. The capsular ligament is attached to its inner part throughout its whole length, the *lateral* and the *medial bands of the ilio-femoral ligament* are attached to its upper and lower halves respectively outside the capsular ligament and the *vastus lateralis* arises from its upper-half while the *vastus medialis* arises from its lower-half external to the ilio-femoral ligament.

The TROCHANTERIC CREST marks the line of junction between the body and the neck posteriorly. The

the third and the fourth toes receives insertion of the *corresponding dorsal interosseous* muscle respectively. The medial side of the base of the proximal phalanx of the second toe receives insertion of the first dorsal interosseous muscle. The first and the second plantar interossei are attached to the medial aspect of the base of the proximal phalanx of the third and the fourth toes respectively.

Structure of the bones of the foot. The structure of the bones of the foot is same as that of the bones of the hand. The nutrient foramen is found on the

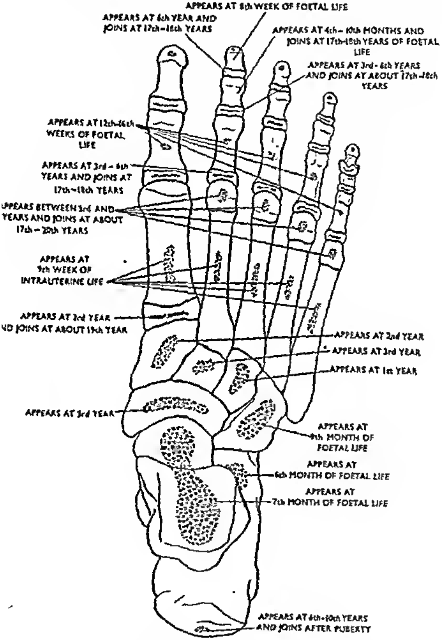


Fig. 375. A plan of ossification of the skeleton of the foot.

plantar aspect and the nutrient canal is directed towards the head in the first metatarsal and towards the base in other metatarsal bones. The nutrient canal may be absent in the phalanges of the toes, when present, it is directed towards the base.

Ossification of the bones of the foot. Tarsal bones—All the tarsal bones ossify from one primary centre of ossification except the calcaneum which has an

additional secondary centre for its posterior tubercles. The primary centre for the calcaneum appears at sixth month; its secondary centre for the medial and lateral tubercles (posterior tubercles) appears at 8th to 10th years and unites with the rest of the bone between fifteenth and eighteenth years. The primary centre for the cuboid appears at birth, that for the lateral cuneiform bone at first year, navicular at third year and the intermediate and medial cuneiform hones at fourth year.

METATARSAL BONES. Each of the metatarsal bones ossifies from one primary centre for the body which appears at ninth week of foetal life and from one secondary centre for its epiphyseal end. The secondary centre for the base of the first metatarsal appears at 3rd year and unites with the body at eighteenth year. The secondary centre for the head of the other metatarsals appears at third year and unites with the body at eighteenth year.

PHALANGES. Each phalanx has one primary centre for the body and head, and one secondary centre for the base.

The primary centre for the distal phalanx appears at the end of third month of foetal life, that for the proximal phalanx at the end of fourth month and for the middle phalanx at sixth month to birth. The secondary centre for the base appears at third year and unites with the body between fifteenth and eighteenth years.

THE CRANIAL OR THE SKULL BONES

The cranial bones including the mandible are twenty-two in number and they are as follows :

(1) Occipital	1	(8) Ethmoid	1
(2) Parietal	2	(9) Palatine	2
(3) Frontal	1	(10) Maxilla	2
(4) Temporal	2	(11) Zygomatic	2
(5) Sphenoid	1	(12) Nasal	2
(6) Lacrimal	2	(13) Vomer	1
(7) Inferior nasal concha	2	(14) Mandible	1

THE OCCIPITAL BONE

The occipital bone is situated at the postero-inferior part of the cranium. It is trapezoid in shape and presents a concavity forwards and a convexity backwards. It encloses a large oval foramen, the *foramen magnum* through which the cranial cavity communicates with the vertebral canal. The expanded plate of bone behind the foramen magnum is known as the *squamous part* and the quadrilateral piece of bone in front of it is the *basilar part*, and on either side of the foramen is the *lateral part (condylar part)* which links up the basilar and the squamous parts.

Squamous part. The squamous part of the occipital bone consists of an *external* and an *internal surface*, *superior* and *lateral angles* and *lambdoid* and *mastoid borders*.

External surface. The external surface is convex in all directions and mid-way between its summit and the margin of the foramen magnum it presents a prominence known as the *external occipital protuberance.* It forms an important bony landmark known as the *inion* on the exterior of the skull and can be palpated without any difficulty. The *superior sagittal sinus ends and the transverse sinus begins* opposite this level. It gives attachment to the highest point of the *ligamentum nuchae.* Descending downwards from it in the median plane to the margin of the foramen magnum is a crest known as the *external occipital crest* which gives attachment to the *ligamentum nuchae.* Two arched lines, one above the other, extend lateralwards from each side of the external occipital protuberance and are known as the *highest* and *superior nuchal lines respectively.* The highest nuchal line is less distinct and gives attachment to the *galea aponeurotica* or the *epicranial aponeurosis.* The superior nuchal line is well marked and lies below the highest nuchal line. The superior nuchal line gives origin to

trapezius and *occipital belly of the occipito-frontalis* and insertion to *sternomastoid* and *splenius capitis*. Trapezius is attached medially and the occipital belly of the occipito-frontalis is attached laterally and below the latter the sternomastoid and the splenius capitis are attached. Running laterally from the middle of the external occipital

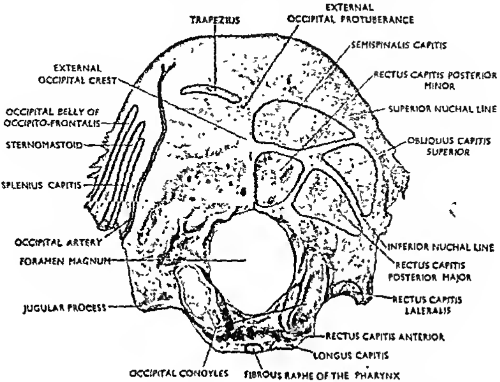


Fig. 376. The external aspect of the occipital bone with attachments and relation.

crest is another arched line known as the *inferior nuchal line*. The portion of the bone above the external occipital protuberance and the highest nuchal line is smooth and featureless and is known as the *planum occipital* which is covered by the galea aponeurotica (epicranial aponeurosis) and the remaining portion of the external surface is rough for muscular impressions and is known as the *planum nuchal* or in other words the plane pertaining to the muscles of the neck. The area in between the superior and inferior nuchal lines gives insertion to *semispinalis capitis* medially and *obliquus capitis superior* laterally. The inferior nuchal line and the area below it give insertion to *rectus capitis posterior minor* medially and *rectus capitis posterior major* laterally. The postero-lateral margin of the foramen magnum gives attachment to the *posterior allanto-occipital membrane* which forms the floor of the sub-occipital triangle in this situation.

The *internal surface* is deeply concave and is divided into four fossae by a cruciate eminence, the limbs of which meet at an irregular prominence, the *internal occipital protuberance* opposite the mid-point between the summit of the bone and the margin of the foramen magnum. The upper two fossae are triangular in form and lodge the posterior ends of the cerebral hemispheres. The lower two are quadrilateral in shape and are occupied by the cerebellum. Extending upwards from the internal occipital protuberance to the summit is the groove for the *superior sagittal sinus* and is known as the *sagittal sulcus*; the margins of the groove give attachment to the *falx cerebri*. Descending downwards and forwards from it towards the foramen magnum is a ridge, the *internal occipital crest* which gives attachment to the *falx cerebelli* and in between the two layers of the falx cerebelli there lies the *occipital sinus* in this situation. Immediately behind the margin of the foramen magnum the internal occipital crest bifurcates to enclose a depressed area known as the *vermian fossa* for the lodgment of the *inferior vermis of the cerebellum*. Extending lateralwards from the internal occipital

protuberance is a transverse groove, the *transverse sulcus* which lodges the *transverse sinus* and the margins of the groove give attachment to the *tentorium cerebelli*. The right transverse sulcus is usually larger than the left and is continuous with the sagittal sulcus and the point of union between the two is marked by a wide depression which lodges the *confluence of the sinuses* formed by the union of the superior sagittal sinus and the right transverse sinus. The *occipital sinus* and the *straight sinus* open into the confluence of sinuses in this situation.

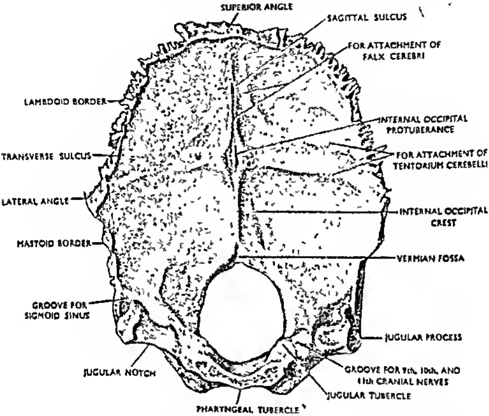


Fig. 377. The internal aspect of the occipital bone

The *superior angle* forms the summit of the squamous part and is formed by the union of the two lambdoid borders. It articulates with the occipital or postero-superior angles of the parietal bones. The *lateral angles* are placed at the ends of the transverse sulci and each is received into the interval between the parietal bone and the mastoid part of the temporal bone. The *lambdoid border* extends from the superior angle to the lateral angle and articulates with the occipital or posterior border of the parietal bone. The *mastoid border* extends from the lateral angle to the jugular process and articulates with the mastoid part of the temporal bone.

Basilar part. The basilar part of the occipital bone projects upwards and forwards from the foramen magnum and consists of *anterior, superior* and *inferior surfaces* and *posterior* and *two lateral borders.*

The *anterior surface* is rough and quadrilateral in shape and articulates with the body of the sphenoid by means of a plate-like cartilage which undergoes ossification at the 25th year of life (primary cartilaginous joint).

The *superior surface* is hollowed out and smooth and is known as *clivus* which lodges the lower part of the *pons* and the *medulla oblongata*. On either side, close to the lateral margin it presents a slight groove *the inferior petrosal sulcus* which lodges the *inferior petrosal sinus*. The two inferior petrosal sinuses are connected with each

other by a network of veins which occupies the superior surface of the basilar part and is known as the *basilar sinus*. The posterior part of the superior surface close to the margin of the foramen magnum gives attachment to the following ligaments in order from above downwards and backwards.

(1) *Membrana tectoria.*
(2) *Upper band of the cruciate ligament of the atlas.*
(3) *Apical ligament.*
(4) *Anterior atlanto-occipital membrane.*

The *inferior surface* is rough and convex in its general outline. Opposite to the median plane about $\frac{1}{2}''$ in front of the foramen magnum there is a small tubercle known as the *pharyngeal tubercle* for the attachment of the *fibrous raphe from the pharynx.* On either side of this tubercle this surface gives insertion to the *longus capitis* muscle and the depression in front of the condyle gives insertion to *rectus capitis anterior.*

The *lateral margin* of the basilar part articulates with the petrous part of the temporal bone. The *posterior margin* is formed by the anterior margin of the foramen magnum and gives attachment to *anterior atlanto-occipital membrane.*

Lateral parts (Condylar parts). The condylar part of the occipital bone is situated on each side of the foramen magnum and forms a link between the basilar part and the squamous part. Inferiorly each condyle presents a convex articular surface, the *occipital condyle* which articulates with the superior concave articular facet of the atlas. Each occipital condyle is either oval or kidney-shaped and its articular surface faces downwards and laterally. The long axis of the occipital condyle is directed forwards and medially so that their anterior ends are closer together and their posterior ends are wide apart. Immediately above the anterior end of each condyle is the anterior opening of the hypoglossal canal which transmits the *hypoglossal nerve, meningeal branch of the ascending pharyngeal artery* and *an emissary vein* connecting the basilar venous plexuses with the pterygoid venous plexus. Behind the posterior end of each condyle is a depression, the *condylar fossa* which receives the posterior part of the superior facet of the atlas when the head is bent backwards. Sometimes the condylar fossa is perforated by the *condylar canal* which transmits *an emissary vein* which connects the sigmoid sinus with the veins of the sub-occipital triangle. The superior surface of the condylar part is formed by a rounded eminence known as the *tuberculum jugulare* which bridges across the hypoglossal canal. The posterior part of the tuberculum jugulare presents a shallow groove which lodges the *glossopharyngeal, vagus* and *accessory nerves.* The medial aspect of the condyle presents a rough area or a tubercle which gives attachment to the *alar ligament.* The circumferential margin of the occipital condyle gives attachment to the *capsular ligament of the atlanto-occipital joint.*

From the junction of the condylar part and the squamous part, a short process projects lateralwards and is known as the *jugular process.* It consists of superior, inferior, anterior and lateral surfaces. The superior surface presents a curved groove which lodges the *terminal portion of the sigmoid sinus.* The inferior surface is rough and gives attachment to *rectus capitis lateralis.* On this surface there is a small eminence known as the *para mastoid process.* This para mastoid process, in certain percentage of cases, may be sufficiently long to articulate with the transverse process of the atlas. The anterior surface of the jugular process presents a concavity known as the *jugular notch* which in the articulated skeleton, forms the posterior boundary of the jugular foramen. The jugular foramen is divided into anterior, posterior and intermediate compartments by two bony spicules known as the *intrajugular processes.* The anterior compartment transmits the *inferior petrosal sinus*; the posterior compartment transmits the *internal jugular vein* while the intermediate compartment transmits the *glossopharyngeal, vagus* and *accessory nerves.* One of the meningeal branches of the ascending pharyngeal artery and an emissary vein may also pass through this foramen. The lateral surface of the jugular process forms a quadrilateral articular surface which articulates with the similar surface on the inferior aspect of the petrous part of the temporal bone through the medium of a cartilage forming a primary cartilaginous joint (synchondrosis). After 25th year the cartilage becomes ossified.

Foramen magnum. The foramen magnum is an oval aperture in the occipital bone around which there lies the different portions of the bone, namely, the basilar part in front, the squamous part behind, and the condylar part on either side. It is wider behind than in front and its longest diameter passes antero-posteriorly opposite to the median plane. The *alar ligament* which is attached to the tubercle on the medial part of the condyle incompletely subdivides the foramen magnum into a smaller anterior compartment and a larger posterior compartment. The anterior compartment transmits the *odontoid process of the axis, the apical ligament, upper band of the cruciate ligament of the atlas* and the *membrana tectoria;* the larger posterior compartment transmits the *lower end of the medulla oblongata* and *its coverings* (dura mater, arachnoid mater and the pia mater) and along it in the subarachnoid space the following structures pass.

(1) *Spinal portion of the accessory nerve* .. .. (2) *Two vertebral arteries with the plexus of sympathetic nerves.*	Ascending
(3) *Anterior and posterior spinal arteries*	Descending

The anterior margin of the foramen magnum gives attachment to the anterior atlanto-occipital membrane and its posterior margin to posterior atlanto-occipital membrane. The foramen magnum communicates the posterior cranial fossa with the vertebral canal.

Ossification. The occipital bone comes to the formation of both the vault as well as the base of the cranium, and before ossification it is preformed partly in membrane and partly in cartilage. The portion of the squamous part that lies above the highest nuchal line (planum occipitale) is preformed in membrane while the rest of the bone is preformed in cartilage.

The bone ossifies from seven centres, two for the membranous portions above the highest nuchal line, two for the rest of the squamous part, one for each of the condylar part and one for the basilar portion. The two centres for the membranous portion appear at the eighth week of intrauterine life, one on each side of the median plane and soon unite to form the upper or interparietal division of the squamous part. The two centres for the rest of the squamous part, one on each side of the median plane, appear at the seventh week of intrauterine life and soon fuse together to form the lower or supra-occipital division of the squamous part, and the upper and the lower divisions of the squamous part, or the interparietal and the supra-occipital divisions, fuse together at about the third month of intrauterine life. The centre for the condylar part appears during the eighth week of intrauterine life and that for the basilar part appears at the sixth week. At the fourth year the squamous part unites with the condylar parts which again unite with the basilar part at about the sixth year. Thus at about the sixth year the bone becomes a single piece. The basilar part unites with the body of the sphenoid between eighteenth and twenty-fifth years.

N.B. Sometimes the interparietal portion of the squamous part remains separate either as a single piece or as two pieces and remains united with the rest of the bone by sutures or fissures and when it so exists it is called the *interparietal bone.*

The squamous part, as it is known, unites with the condylar part during the fourth year of life and at birth the two portions remain united through the medium of a band of cartilage. This joint is called the *obstetrical* hinge-joint (Budin) because it allows limited see-saw movement during the process of delivery of the foetus and thus allows moulding of the foetal head in which its diameters and form are modified to suit the passage of the foetus through the birth canal,

The posterior margin of the foremen magnum, according to some authority, occasionally ossifies from a separate centre known as the *Kerckring centre* which appears during the sixteenth week and unites with the rest of the bone before birth. Frazer declines to admit the existence of such a centre and he infers that greater part of the margin of the foramen magnum is formed by the condylar part, and a small portion in front, by the basilar part, and a similar small portion by the squamous part posteriorly, and before ossification the posterior margin of the foramen magnum is drawn

out into a blunt angle—the *posterior incisura.* According him this blunt angle is gradually closed up during the process of ossification and sometimes the process of extension of ossification to this angle may result in the formation of a tongue-like process in this situation known as *Kerckring process.*

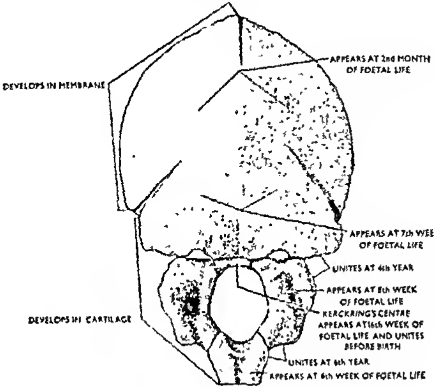


Fig. 378. The external aspect of the occipital bone after birth.

THE PARIETAL BONES

The parietal bones are two in number and by their union form the greater part of the vault and the sides of the cranium. Each is irregularly quadrilateral in shape and consists of two surfaces, four borders, and four angles. Its surfaces are external and internal. Its borders are *sagittal* (superior), *squamosal* (Inferior), *frontal* (anterior) and *occipital* (posterior) and its angles are *frontal* (antero-superior), *sphenoidal* (antero-inferior), *occipital* (postero-superior) and *mastoid* (postero-inferior). The external surface is convex while the internal surface is deeply concave. The sagittal border is the longest one and is thickly serrated. The squamosal border forms an arched border and its anterior two-thirds are bevelled at the expense of its outer surface while its posterior one-third is thickly serrated. The sphenoidal angle is thin and projecting downwards and is bevelled at the expense of its outer surface.

Side determination. Hold the bone in such a way that its sphenoidal angle (antero-inferior angle) looks downwards and forwards, the sagittal or superior border which is straight and thickly serrated lies above to face the median plane, the arched inferior border looks downwards and the convex external surface will determine the side to which the bone belongs.

External surface. The external surface is convex in all the directions and presents near its centre a rounded eminence known as the *parietal tuber* (*eminence*). The importance of the parietal eminence is that (*a*) it forms an important bony landmark; (*b*) the maximum transverse diameter of the skull corresponds to this eminence; (*c*) the centre of ossification first starts at this point and then spreads out in a radiating manner; (*d*) it corresponds to the upper end of the lateral sulcus of the cerebral hemisphere and that the centre for written and printed words

marginal gyri) lies opposite this level. Two arched lines situated one above the other known as the *superior* and *inferior temporal lines* traverse this surface from before backwards. The superior temporal line gives attachment to *temporal fascia* and the inferior temporal line gives origin to the *highest fibres of the temporalis muscle*. The portion of the bone above these lines is covered by the galea aponeurotica (*epicranial aponeurosis*) and that below these lines forms a part of the temporal fossa. About 2 inches in front of the occipital or postero-superior angle and close to the superior border there is a foramen, the *parietal foramen*, which transmits a branch from the *occipital artery* and an *emissary vein* which connects the superior sagittal sinus with the occipital vein.

Internal surface. The internal surface is deeply concave and is marked by impressions of the cerebral gyri and of the branches from the middle meningeal vessels. Opposite the sagittal (superior) border it presents a longitudinal shallow groove which with a similar groove on the opposite side forms the *sagittal sulcus* which lodges the *superior sagittal sinus* and its margin gives attachment to the *falx cerebri*. Close to

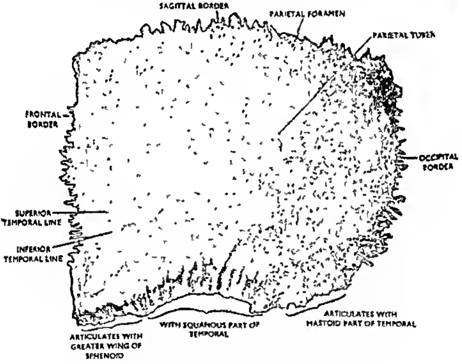


Fig. 379. The left parietal bone. External aspect.

the sagittal sulcus there are a number of granular foveolae (pits) for the lodgements of *arachnoidal granulations.* The impression for the anterior branch of the middle meningeal artery begins from the inner surface of the antero-inferior angle and soon divides into two, one lies at a distance of about ¼ an inch from the anterior border and runs parallel to it while the other runs upwards and backwards. Another groove that runs upwards and backwards at a close distance from the postero-inferior angle is caused by the posterior division of the middle meningeal artery. The branches of the middle meningeal artery lie in between the dura mater and the cranium and the vascular impression is actually produced by the middle meningeal sinus and not by the artery. Opposite the postero-inferior angle this surface presents an arched groove which lodges the end of the *transverse sinus* and the *commencement of the sigmoid sinus.*

The *sagittal* or *superior border* is the longest and the thickest. It is straight and thickly serrated and articulates with the fellow of its opposite side to form the *sagittal*

suture. The *squamosal* or *inferior border* is arched and is divided into three portions —anterior, intermediate and posterior. The anterior portion is bevelled at the expense of its outer surface and articulates with the greater wing of the sphenoid. The intermediate portion is arched and bevelled at the expense of its outer surface and articulates with the squamous part of the temporal bone. The posterior portion is straight and thickly serrated and articulates with the mastoid part of the temporal

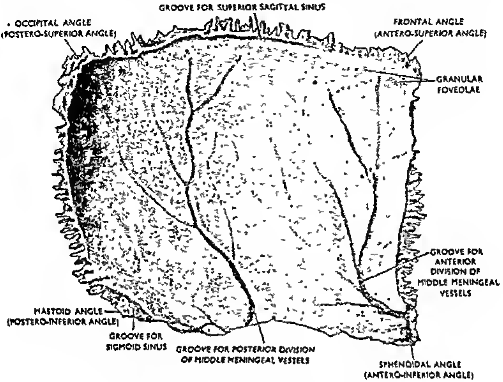


Fig. 380. The left parietal bone. Internal aspect.

bone. The *frontal* or *anterior border* is serrated and is bevelled at the expense of its inner surface above and outer surface below and articulates with the posterior border of the frontal bone to form half of the *coronal suture*. The *occipital* or *posterior border* is also thick and serrated and articulates with the lambdoid border of the squamous part of the occipital bone to form half of the *lambdoid suture*.

The *frontal* or the *antero-superior angle* is formed by the union of the sagittal and frontal borders and forms almost a right angle and corresponds to the point of union between the sagittal and coronal sutures and this point on the skull is called the *bregma*. The *sphenoddal* or the *anterior-inferior angle* is very thin and in the articulated skull it forms the meeting point of four bones known as the *pterion*. The four bones that meet at the pterion are the *frontal, parietal, greater wing of the sphenoid* and the *squamous part of the temporal bone*. The anterior branch of the middle meningeal artery lies in close relation to the internal surface of the antero-inferior angle. The *occipital or postero-superior angle* corresponds to the *lambda* of the articulated skull and marks the line of union between the sagittal suture and the lambdoid suture. The *mastoid* or the *postero-inferior angle* corresponds to the *asterion* or the meeting point of three bones on the skull and the bones are the *postero-inferior angle of the parietal bone, lateral angle of the occipital bone* and *the mastoid part of the temporal bone*.

Ossification. The parietal bone is a membrane bone and ossifies from two centres. The two centres, one above the other, appear at the site of the future parietal eminence during the seventh week of intrauterine life and soon fuse together. From this the ossification radiates towards the margins of the bone and at birth the

angles of the parietal bone still remain to be membranous and these unossified membranous gaps are called the *fontanelles* (anterior, posterior, antero-inferior and postero-inferior). Except the anterior fontanelle which closes by ossification during eighteenth month of post-natal life all others close soon after birth.

FONTANELLES

The unossified membranous gaps in the skull at birth are known as *fontanelles* and they are altogether six in number, two occupying the median plane and two on the lateral aspect of each side of the skull. They correspond to the four angles of the parietal bone and those on the median plane, that is, those corresponding to the antero-superior and the postero-superior angles of the parietal bone, are known as the *anterior* and *posterior fontanelles* respectively and those corresponding to the antero-inferior and postero-inferior angles are called the *antero-lateral* and *postero-lateral fontanelles* respectively.

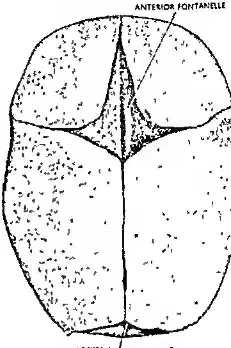


Fig. 381. A foetal skull. Seen from above.

Functions of fontanelles. (1) They allow overlapping and moulding of the skull during birth of the baby.

(2) Further growth of the brain is permitted due to their presence.

Anterior fontanelle. It is placed at the junction of the sagittal and coronal sutures and is diamond-shaped. It measures about one and a half inches in length and one inch in breadth. It consists of *anterior, posterior* and *two lateral angles* and four sides.

Importance and significance—

(1) *Developmental importance.* Usually in normal condition the membranous gap of the anterior fontanelle is replaced by bony tissue by the eighteenth month. Any delay in closure of the gap indicates defective bone formation. Age of the child may be ascertained by seeing this development.

(2) *Surgical importance.* Puncture of the lateral ventricle of the brain may be done by pushing a needle through the lateral angle of the fontanelle. Intravenous injection or withdrawal of blood may be done by puncturing the superior sagittal sinus which lies opposite to the median plane just beneath the skin and the membrane.

(3) *Medical importance.* Abnormal bulging or sinking of the fontanelle indicates increased intracranial pressure or insufficiency of body fluid respectively.

(4) *Obstetrical importance.* While doing a vaginal examination palpation of this will indicate the position of the baby.

Posterior fontanelle. It is triangular in shape and is situated at the junction of the sagittal suture and the lambdoid suture. It is of less importance and closes shortly after birth.

Other fontanelles, namely, antero-lateral and postero-lateral fontanelles have no practical values except moulding of the foetal skull during birth of the baby and are closed by osseous tissues soon after birth.

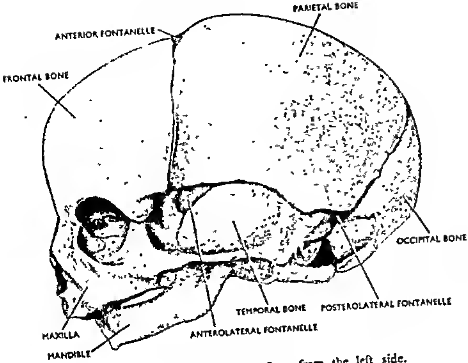


Fig. 382. A foetal skull. Seen from the left side.

THE FRONTAL BONE

The frontal bone forms the region of the forehead and resembles a cockle-shell in appearance. Two triangular plates of bone project backwards from each side of the median plane knwon as the *orbital plates* which form the roof of the corresponding orbital cavity. The frontal bone consists of four surfaces and two orbital plates. The surfaces are *frontal* or *external*, *cerebral* or *internal* and *two temporal*.

Frontal surface. The frontal surface is smooth and convex in its general outline. It is separated from the orbital plate by a sharp margin known as the *supraorbital margin*. The frontal bone in early embryonic life consists of two different segments of bones which unite by suture opposite to the median plane. Usually after birth as growth continues the line of fusion or the suture becomes osseously continuous with each other and in fully formed bone there is no existence of such sutures at all but in certain percentage of cases (9 per cent) remains of the *frontal* or *metopic suture* exists opposite to the lower part of the median plane. On each side of the median plane about 3 cm. above the supraorbital margin there is a rounded eminence known as the *frontal tuber* (*frontal eminence*). Immediately above the supraorbital margin two arched eminences, one on each side, are called the *superciliary arches* which meet in the median plane to form a smooth elevation known as the *glabella*. The superciliary arches are caused by the presence of the frontal air sinuses within the bone and their prominence to some extent depends upon the relative prominence of the frontal air sinuses. Each superciliary arch is separated from the frontal eminence by a shallow arched groove. The supraorbital margin which forms the upper circumferential margin of the orbital opening is sharp and prominent along its outer two-thirds but its medial one-third is more or less rounded. At the junction of the outer two-thirds and the inner one-third there is a notch or a foramen known as the *supraorbital notch* or *foramen* which transmits the supraorbital vessels and nerves. Medial to the supraorbital notch there is another *notch* or *foramen* known as the *frontal* (*supratrochlear*) *notch* or *foramen*, for the transmission of the corresponding vessels and nerves. Laterally the supraorbital margin ends in a thick process the *zygomatic process* which articulates with the frontal process of the zy-

bone. Curving upwards and backwards from the zygomatic process is an arched line which soon divides into *superior* and *inferior temporal lines* and separate the frontal surface from the temporal one.

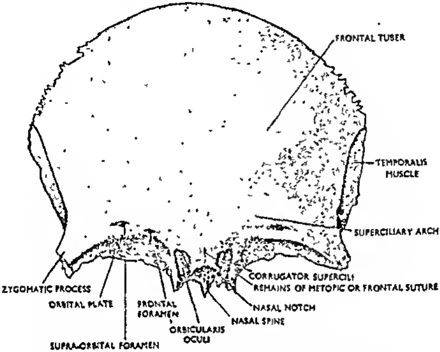


Fig. 383. The frontal bone with attachments. Seen from the front.

Below the glabella and between the supraorbital margins the portion of the bone projecting downwards is known as the *nasal part of the frontal bone.* It presents an irregular articular notch known as the *nasal notch* which articulates from medial to lateral side, with the nasal bone, frontal process of the maxilla and the lacrimal bone. From the lower part of the nasal notch, opposite the median plane, a pointed process projects downwards and is known as the *nasal spine.* The nasal spine forms a part of the septum of the nose and articulates in front with the crest formed by the two nasal bones and behind with the anterior border of the perpendicular plate of the ethmoid. On either side posteriorly it presents a narrow grooved area which forms the roof of the corresponding nasal cavity.

Cerebral or internal surface. The cerebral or the internal surface is deeply concave and is occupied by the frontal lobe of the cerebral hemisphere. Opposite to the median plane this surface presents a shallow groove, the *sagittal sulcus,* which lodges the superior sagittal sinus. The margins of the groove, as they descend downwards, converge together and are joined to form a crest known as the *frontal crest.* The margins of the groove together with the frontal crest give attachment to the falx cerebri. Close to the sagittal sulcus there are numerous *granular foveolae* (pits) for the lodgement of the arachnoid granulations. The frontal crest ends below into a notch which articulates with the alae of the crista galli of the ethmoid and forms a foramen, the *foramen caecum,* which transmits an emissary vein connecting the superior sagittal sinus with the veins of the nasal fossa. On either side of the sagittal sulcus the internal surface presents irregular impressions for the cerebral gyri and furrows for meningeal vessels.

Temporal surfaces. The temporal surface forms a part of the temporal fossa and is limited above by the superior temporal line. The superior temporal line

gives attachment to the temporal fascia and the inferior temporal line together with the surface below it gives origin to the temporalis muscle.

The PARIETAL MARGIN articulates with the parietal bones on each side of the median plane and forms the coronal suture. *A rough triangular articular area* behind the zygomatic process articulates with the greater wing of the sphenoid bone.

Orbital plates. The orbital plates of the frontal bone consist of two triangular plates of bone, each of which forms the roof of the corresponding orbital cavity and the two plates are separated from each other by a wide gap known as the *ethmoidal notch*. Each orbital plate consists of inferior or orbital and superior or cerebral surfaces and posterior and medial margins. The latter is formed by the margins of the ethmoidal notch.

The *orbital* or *inferior surface* is concave and forms the roof of the orbital cavity. Its lateral portion forms a deep depression known as the *lacrimal fossa* and lodges the lacrimal gland. Its medial portion immediately below the medial end of the supraorbital margin and in between the supraorbital notch and the fronto-lacrimal suture presents a fossa or a spine *trochlear fossa or spine* (fovea vel spina trochlearis) for the attachment of the fibrocartilaginous pulley of the superior oblique muscle of the eyeball.

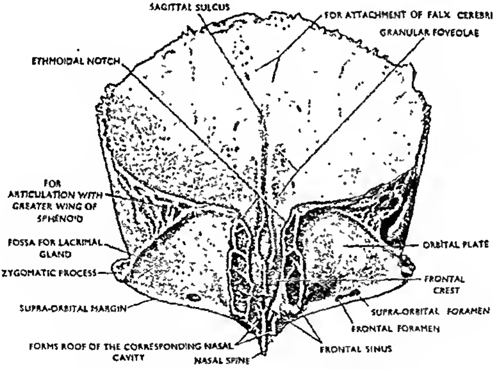


Fig. 384. The frontal bone. Seen from below and behind.

The *superior* or *cerebral surface* presents irregular impressions for the cerebral gyri on the inferior surface of the frontal lobe of the brain and minute furrows for the meningeal branches of the ethmoidal vessels.

The *posterior border* articulates with the anterior border of the lesser wing of the sphenoid and its medial margin which is irregular, forms the margin of the ethmoidal notch.

The *ethmoidal notch* in the articulated skull is filled up by the cribriform plate of the ethmoid and the margins of the notch which present broken air cells articulate with the upper surface of labyrinth of the ethmoid and completes the ethmoidal air sinuses. Two transverse grooves known as the *anterior* and *posterior ethmoidal grooves* traverse the margin of the ethmoidal notch and together with the similar grooves on

the upper surface of the labyrinth of the ethmoid they are converted into *anterio* and *posterior ethmoidal canals* which transmit the corresponding vessels and nerve At the anterior end of each margin of the ethmoidal notch is a large opening, th opening of the *frontal air sinus which communicates with the middle meatus of the nos through the fronto-nasal duct.*

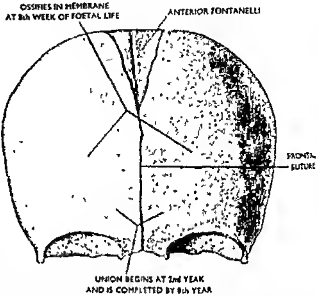


Fig. 385. The frontal bone at birth. Note that the frontal bone remains in two halves at birth which are united together at the frontal suture.

FRONTAL AIR SINUS (See also para-nasal sinuses). The frontal air sinuses are two in number and are placed on either side of the median plane and are formed at the expense of the deploic layer of the frontal bone opposite the region of the glabella and the superciliary arches. They are extremely variable in shape and size and may be altogether absent in certain percentage of cases. They are separated from each other by a median septum which may deviate to one or the other side. Each is roughly triangular in shape and corresponds to a triangular area mapped out by three points—one in the nasion, one in the median plane about one inch above the nasion and the third on the supraorbital margin at its junction of the medial one-third with the lateral two-thirds. Each is lined by mucous membrane derived from the nasal cavity.

Measurements. In length one and a half inches; in breadth one inch, and about half an inch anteroposteriorly.

Communication. It communicates with the middle meatus of the corresponding nasal cavity through the fronto-nasal duct.

Ossification. The frontal bone is preformed in membrane and begins to ossify at the eighth week of intrauterine life from two primary centres, one on each side close to the region of the superciliary arch. From this point the ossification spreads upwards, backwards and downwards to form the squama, orbital plate and the nasal part respectively. Occasionally two secondary centres of ossification may appear at the nasal spine during the tenth year of life. At birth the frontal bone is seen to be divisible into two symmetrical halves by a median sature, the *frontal suture* (metopic suture). The two halves begin to fuse together at the upper part during the second year and the fusion gradually extends downwards till the two halves are completely united by the eighth year. Occasionally the two halves may not fuse at all resulting in the persistence of the frontal suture or occasionally only the lower portion of the frontal suture persists. A sutural bone (wormian) may occasionally appear either at the lower or at the upper portion of the frontal suture.

THE SPHENOID BONE

The sphenoid bone is situated at the base of the skull in front of the petrous part of the temporal bone and the basilar part of the occipital bone. It resembles a bat with wings outstretched and consists of a body, two greater and two lesser wings and two pterygoid processes.

Body. The body of the sphenoid is cubicle in shape and possesses six surfaces —superior, inferior, anterior, posterior and two lateral.

The *superior or cerebral* surface of the body is irregular and presents anteriorly an irregular bony projection known as the *ethmoidal spine* which articulates with the posterior border of the cribriform plate of the ethmoid. Behind the ethmoidal spine the superior surface presents a smooth area known as the *jugum sphenoidale.* It forms the part of the anterior cranial fossa and supports the gyrus rectus and the olfactory tract. Behind this there is a ridge which forms the anterior boundary of a transverse groove known as the *optic groove.* The optic groove leads laterally into the *optic canal* which transmits the *optic nerve, ophthalmic artery* and the *cerebral meninges.* In the *optic canal* the optic nerve lies medial to the ophthalmic artery. Behind the optic groove is a rounded elevation known as the *tuberculum sellae.* On

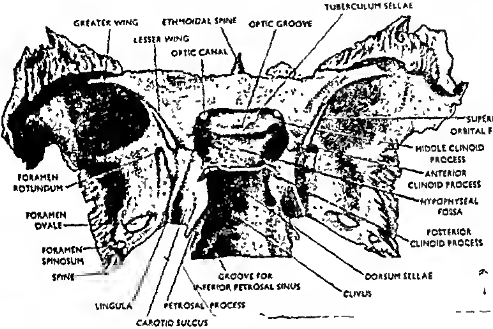


Fig. 386. The sphenoid bone. Seen from above.

each side of this and separated from it by a notch is the *middle clinoid process.* Behind the tuberculum sellae and the middle clinoid processes is a deep depression known as the *sella turcica.* Its deepest portion lodges the *hypophysis cerebri* and is known as the hypophyseal fossa. The anterior margin of the sella turcica lodges the *anterior intercavernous sinus* while its posterior margin lodges the *posterior intercavernous sinus.* Posteriorly the sella turcica is overhung by a square plate of bone known as the *dorsum sellae.* Its superior angles form conical projections termed the *posterior clinoid processes* which give attachment to the attached border of the tentorium cerebelli. The posterior part of the dorsum sellae at its lateral angles are projected lateralwards which articulate with the apex of the petrous part of the temporal bone and are known as the *petrosal processes.* The smooth concave area on the posterior part of the dorsum sellae is known as the *clivus* and supports the upper part of the pons. In the articulated skull it is uninterruptedly continuous with basilar part of the occipital bone.

The *inferior surface* of the body of the sphenoid forms the roof of the posterior part of the corresponding nasal cavity on either side of the median plane. It presents a triangular spine opposite to the median plane known as the *sphenoidal rostrum* which articulates with the fissure in the superior border of the vomer. On either side, a thin plate of bone extends from the medial pterygoid plate and overhangs the lateral part of this surface and is known as the *vaginal process.* In between

the vaginal process and the rostrum the apex of the lower triangular part of the sphenoidal concha intervenes and articulates with the ala of the vomer.

The *anterior surface* is irregular and presents a crest opposite the median plane known as the *sphenoidal crest* which articulates with the posterior border of the *perpendicular plate* of the ethmoid and forms a part of the nasal septum. On either side of the sphenoidal crest inferiorly is a rounded opening which leads into the sphenoidal air sinus within the body of the sphenoid. The sphenoidal air sinus communicates with the spheno-ethmoidal recess at the *upper* and *posterior part of the superior meatus of the nose.* On either side of the median plane the anterior surface of the body presents an upper lateral *depressed area* and a lower smooth *triangular area.* The upper lateral depressed area is filled up by the posterior part of the labyrinth of the ethmoid and its lateral margin articulates with the orbital plate of the ethmoid above and with the orbital process of the palatine bone below. The lower smooth triangular area forms part of the roof of the nasal cavity. At the junction of these two areas and situated on either side of the median plane is the rounded opening of the sphenoidal air sinus.

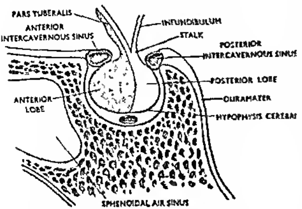


Fig 337 A sagittal section of the body of the sphenoid together with the hypophysis cerebri

The *posterior surface* articulates with the basilar part of the occipital bone by a plate-like hyaline cartilage which undergoes ossification at the 25th year and the two bones become osseously continuous with each other.

The *lateral surfaces of the body are fused* with the two greater wings, one on each side. At the junction of the body with the greater wing superiorly there is a shallow anteroposterior groove known as the *carotid sulcus* and lodges the caverrous sinus which contains the *internal carotid artery with carotid plexus of sympathetic, the oculomotor, trochlear, ophthalmic division of the trigeminal and the abducent nerves.* Anteriorly the carotid sulcus opens into the superior orbital fissure whereas posteriorly it ends into the foramen lacerum. Its posterior part is deeper and is overhung medially by the *petrosal process* and laterally by a thin plate of bone known as the *lingula* which hides the posterior opening of the pterygoid canal.

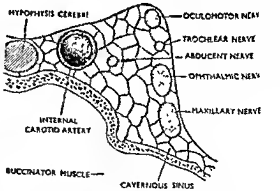


Fig 338. A coronal section of the hypophysis cerebri and the cavernous sinus.

Greater wings. The greater wings of the sphenoid are two strong processes that project lateralwards from the sides of the body and each is bent on itself both laterally and in front. Its postero-lateral part is wedged in between the squamous and petrous parts of the temporal bone and is more or less triangular in form. From its postero-lateral angle (the angle that fits in the notch between the petrous and the squamous parts of the temporal bone) a pointed bony process projects downwards and is known as the *spine* of the sphenoid. By its tip it gives attachment to the *sphenomandibular ligament, anterior ligament of malleus* and to *pterygospinous ligament* and origin to some fibres of the

tensor palati muscle on its medial aspect. On its medial side there is a shallow groove which forms a part of the sulcus tubae on the base of the skull and lodges the cartilaginous portion of the auditory (pharyngo-tympanic) tube and more inferiorly its medial aspect is crossed by the *chorda tympani nerve* and presents a small groove for the same. Laterally the spine is crossed by the auriculotemporal nerve. Besides the spine the greater wing of the sphenoid presents superior, lateral and orbital surfaces, posterior and squamosal borders, an apex and a rough triangular articular area that lies medial to the apex.

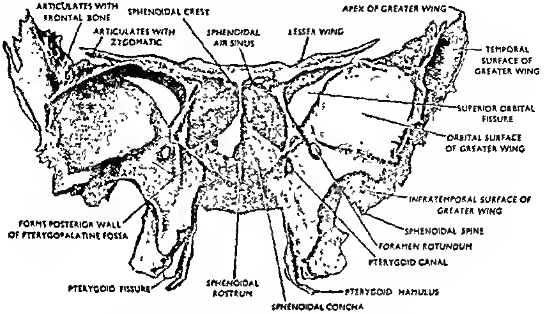


Fig. 389. The sphenoid bone. Seen from the front.

The *superior* or *cerebral surface* is concave and in the articulated skull forms a greater part of the middle cranial fossa. It is marked by irregular depressions formed by the temporal gyri and is filled up by the temporal lobe of the brain. At its antero-medial part it presents a rounded foramen, the *foramen rotundum* which in the articulated skull opens anteriorly into the posterior wall of the pterygopalatine fossa and transmits the maxillary nerve. Behind and lateral to this is an oval aperture known as the *foramen ovale* and transmits the sensory part of the mandibular nerve, its motor root, the accessory meningeal vessels and sometimes, lesser superficial petrosal nerve, the anterior middle meningeal sinus and an emissary vein that connects the cavernous sinus with the peterygoid venous plexus. Lateral to the foramen ovale and antero-medial to the spine is a foramen, the *foramen spinosum* which transmits the meningeal branch of mandibular nerve (nervus spinosus) and the middle meningeal vessels with its plexus of sympathetic. On the bar of bone between the foramen spinosum and ovale there may sometimes be present a small canal which transmits the lesser superficial petrosal nerve when it does not pass through the foramen ovale. Medial to foramen ovale sometimes a small aperture may be present, and when it exists, it is known as the *emissary sphenoidal foramen* (foramen Vesalii) and transmits an emissary vein that connects the cavernous sinus with the pterygoid venous plexus.

The *lateral surface* of the greater wing is convex in its general outline and is divided into an upper or temporal surface and a lower or infratemporal surface by a transverse crest known as the *infratemporal crest*. The temporal surface is concave from before backwards and forms a part of the temporal fossa and gives origin to the temporalis muscle. The infratemporal surface together with the infratemporal crest gives origin to the *upper head of the lateral pterygoid muscle*. The infratemporal crest forms a triangular impression medially which serves to strengthen the attach-

ment of the lateral pterygoid muscle (upper head). From the medial end of th triangular impression a smooth ridge descends downwards to become continuou with the anterior border of the lateral pterygoid plate. In the articulated skull i forms the anterior boundary of the infratemporal fossa and the posterior boundar of the pterygo-palatine fissure. The infratemporal surface presents the lowe openings of the foramen ovale and foramen spinosum. The deep temporal nerv runs forwards and laterally from the foramen ovale and comes into intimate relatio to this surface. The masseteric nerve passes laterally behind the deep tempor nerve on this surface.

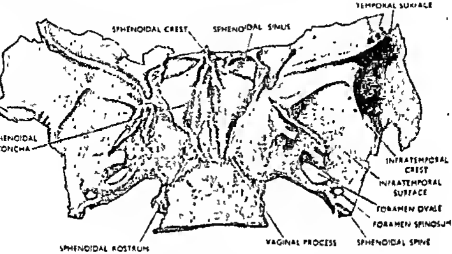


Fig. 390. The sphenoid bone. Seen from below.

The *orbital surface* of the greater wing is quadrilateral in shape and forms tl posterior part of the lateral wall of the orbital cavity. It is directed forwards ar medially and presents four borders—upper, lower, lateral and medial. Its upp border is articular and articulates with the lateral part of the orbital plate of the front bone. Its inferior border is smooth and forms the posterolateral boundary of tl inferior orbital fissure. Its lateral margin presents a serrated edge which articulat with the superior part of the postero-medial margin of the zygomatic bone. Tl medial margin of the orbital surface is sharp and presents a tubercle in its midd part which gives attachment to the annulus tendineus communis. In the articulat skull it forms the inferior margin of the superior orbital fissure. The orbital surfa comes into relation with the lateral rectus muscle, the lacrimal nerve and the lac mal artery. Below the medial end of the lower margin of the orbital surface is small depressed area which forms part of the posterior wall of the pterygo-palati fossa and presents in this situation the anterior opening of the foramen rotundu

The medial half of the *posterior border* of the greater wing is non-articular a forms the anterior boundary of the foramen lacerum in the articulated skull. lateral half articulates with the petrous part of the temporal bone and forms shallow groove inferiorly, the *sulcus tubae* in the articulated skull. The spine fits the angle between the petrous and the squamous parts of the temporal bone. T *squamosal border articulates* with the squamous part of the temporal bone. The ap of the greater wing is directed upwards and is thin, and bevelled at the expense of its inner surface. It articulates with the antero-inferior angle of the pariet bone at the pterion. The rough triangular articular area medial to the ap articulates with the frontal bone.

Lesser Wings. The lesser wings of the sphenoid form two triangular plat of bone which projects laterally on each side from the upper and anterior part of tl body. It is connected with the body by two roots which enclose between them tl

optic canal. It consists of superior and inferior surfaces and anterior and posterior borders.

The *superior surface* is smooth and is continuous with jugum sphenoidale of the body. In the articulated skull it forms a part of the anterior cranial fossa and lodges the frontal lobe of the brain.

The *inferior surface* forms the superior boundary of the superior orbital fissure which is an oblique space between the greater and the lesser wings. *The superior orbital fissure* is bounded above by the undersurface of the lesser wing of the sphenoid, below by the medial margin of the orbital surface of the greater wing, laterally by the frontal bone in between the greater and the lesser wings and medially by the body of the sphenoid. *The superior orbital fissure* is divided into three compartments by the attachment of the annulus tendineus communis—the portion lateral to the annulus, the portion medial to the annulus and the portion within the annulus.

Structures passing lateral to the annulus

(From cranial to the orbital cavity).

(1) Trochlear nerve.
(2) Frontal nerve.
(3) Lacrimal nerve.
(4) Lacrimal artery.
(5) Orbital branch of the middle meningeal artery.

From orbit to the cranial cavity—

(6) Superior ophthalmic vein lying below the frontal nerve.
(7) Recurrent meningeal branch of the lacrimal artery.

Structure passing through superior orbital fissure and lying within annulus (*from cranial to orbit*)

(1) The two divisions of the oculomotor nerve.
(2) Nasociliary nerve—lying in between two divisions of the oculomotor nerve.
(3) Abducent nerve—lying infero-medial to nasociliary nerve.

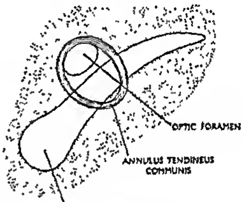


Fig. 391. The position of annulus tendineus communis in relation to superior orbital fissure and the optic foramen.

Structures passing medial to the annulus (*from orbit to cranium*)

(1) Inferior ophthalmic vein.

To summarise the structures passing through the superior orbital fissure may be arranged as follows:

Structures passing from cranial to the orbital cavity

(1) Oculomotor nerve.
(2) Trochlear nerve.
(3) Abducent nerve.
(4) Three branches of the ophthalmic division of the trigeminal nerve (frontal, lacrimal and nasociliary).
(5) The orbital branch of the middle meningeal artery.
(6) Cavernous plexus of sympathetic.
(7) Lacrimal branch of the ophthalmic artery.

From orbit to the cranium—

(1) Recurrent meningeal branch of the lacrimal artery.
(2) Superior and inferior ophthalmic veins.

The inferior surface of the lesser wing is in relation to the *sphenoparietal sinus* posteriorly, and anteriorly, above the optic foramen, it gives origin to the *superior oblique muscle of the eye ball* medially and to the *levator palpebrae superioris* laterally.

The anterior border of the lesser wing is serrated and articulates with the posterior border of the orbital surface of the frontal bone. Its posterior border is rounded and non-articular and *fits into the lateral sulcus of the cerebral hemisphere in the recent state.* It ends medially into a bony projection known as the *anterior clinoid process* which gives attachment to the *free border of the tentorium cerebelli.* Sometimes the anterior clinoid process is long enough to fuse with the middle clinoid process and forms a foramen, the *carotico-clinoid foramen,* which, when exists, transmits the internal carotid artery.

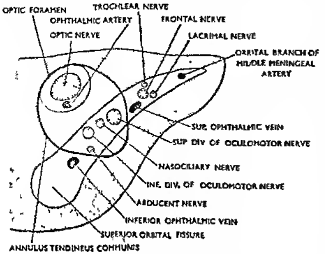


Fig. 392. A general arrangement of the structures in the superior orbital fissure and in the optic foramen at the back of the orbit

Pterygoid processes. The sphenoid bone resembles a bat in appearance and the two pterygoid processes represent the legs of the bat. Each descends downwards from the junction of the body with the greater wing and consists of two plates of bone, the *lateral* and the *medial pterygoid laminae.* Anteriorly, and above, close to their fusion with the body of the sphenoid the two pterygoid plates encroach upon each other and fuse together to form a smooth triangular area which in the articulated skull forms the posterior boundary of the pterygo-palatine fossa. In this situation it presents the anterior opening of the pterygoid canal. Inferiorly, the anterior borders of the two pterygoid plates are separated from each other by a triangular gap—the *pterygoid fissure,* the margins of which articulate with the tubercle of the palatine bone. Posteriorly, the pterygoid plates diverge from each other and form a wedge-shaped fossa between them known as the *pterygoid fossa.* It is divisible into upper and lower areas. The lower area is deeper whereas the upper area forms a shallow depression known as the *scaphoid fossa* which is formed by the splitting of the upper part of the posterior border of the medial pterygoid lamina. The scaphoid fossa gives origin to *tensor palati muscle.* Supero-medial to the scaphoid fossa and in a line with the upper end of the posterior border of the medial pterygoid plate is a small tubercle, the *pterygoid tubercle,* which hides the posterior aperture of the pterygoid canal. The *pterygoid canal* transmits the pterygoid vessels and nerves. The pterygoid nerve is formed by the union of the greater (superficial) petrosal nerve and the deep petrosal nerve from the carotid plexus of sympathetics.

The *lateral pterygoid plate* consists of anterior and posterior borders and lateral and medial surfaces. Its anterior border is non-articular in its upper part where it forms the posterior boundary of the pterygopalatine fissure; in the articulated skull the lower part of the anterior border forms the lateral margin of the pterygoid fissure and articulates with the tubercle of the palatine bone. Its posterior border gives attachment to the pterygospinous ligament. Its lateral surface forms part of the infratemporal fossa and gives origin to the *lower head of the lateral pterygoid muscle.* Its medial surface forms the lateral wall of the pterygoid fossa and gives origin to the *medial pterygoid muscle.*

The *medial pterygoid plate* is longer than the lateral and consists of anterior and posterior borders and lateral and medial surfaces and the pterygoid hamulus. The lower end of the medial pterygoid plate curves laterally to form a hook-shaped process known as the *pterygoid hamulus* which gives attachment to the pterygomandibular ligament and around it the tendon of the tensor palati muscle glides. The

iterior border in most of its extent articulates with the posterior border of the per-ndicular plate of the palatine bone; its lower part forms the medial margin of the erygoid fissure and articulates with the tubercle of the palatine bone. Its posterior order gives attachment to the *pharyngo-basilar fascia* throughout its whole extent, id from its lower part the *superior constrictor* muscle of the pharynx arises. Opposite its mid-point it presents a projection known as the *processus tubarius* which supports e pharyngeal end of the auditory (pharyngotympanic) tube. Its medial surface forms e lateral boundary of the posterior nasal aperture and is covered by mucoperiosteum. ıperiorly the medial surface is prolonged to the undersurface of the body of the henoid as a thin lamina and is known as the *vaginal process* which articulates in ont with the sphenoidal process of the palatine bone, and medially, with the ala of e vomer. Anteriorly, the inferior aspect of the vaginal process presents a small oove which with the sphenoidal process of the palatine bone, is converted into a ınal, the *palatino-vaginal canal* which transmits the *pharyngeal nerve from the spheno-ılatine ganglion* and the *pharyngeal branch from the maxillary artery*. The superior aspect 'the vaginal process together with the ala of the vomer forms a canal known as the *mero-vaginal canal*. Its lateral surface forms the medial boundary of the pterygoid ssa and the tensor palati muscle lies against it.

Sphenoidal concha. The sphenoidal concha covers the anterior and inferior ıpects of the sphenoidal air sinus. It consists of an anterior, vertical, quadrilateral art and a posterior, horizontal, triangular part. The anterior vertical part consists of pper lateral depressed area which is filled up by the labyrinth of the ethmoid and its ıteral margin articulates above with the orbital plate of the ethmoid and with the rbital process of the palatine bone below. The posterior, horizontal, triangular art forms a part of the roof of the corresponding nasal cavity and completes the for-ıation of the sphenopalatine foramen in the articulated skull. Opposite to the ıedian plane the two vertical plates fuse together to form the sphenoidal crest.

Ossification. The sphenoid bone ossifies partly in the membrane and partly ı cartilage. Until lately before birth this bone consists of two parts, *presphenoid* and *ostsphenoid*. The pre-phenoid portion consists f lesser wings and a ıortion of the body that ies in front of the tuber-ıdum sellae, in other vords the whole mass of ıone that lies in front of uberculum sellae. The ›ostshpenoidal part lies ıehind the level of the ıuberculum sellae and consists of the remaining portion of the body, the greater wings and the pterygoid processes. The body, the lesser wings and the medial portions of the greater wings develop in cartilage while the rest of the bone with the exception of the pterygoid hamulus (which develops from cartilage) develop in membrane. The different elements of the bone ossify from 18 centres as follows and are amalgamated together by the 12th year to complete the formation of the bone.

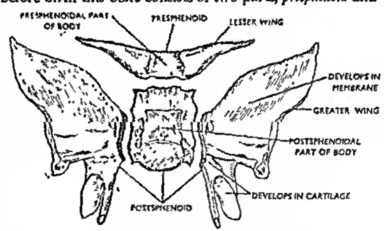


Fig. 393. The developmental parts of the sphenoid bone. The blue portions ossify in cartilage and the rest in membrane.

Body. The body of the sphenoid ossifies from 4 centres, two for the presphenoid part and 2 for the postsphenoid part. The two centres for the presphenoid part, one on each side, appear at the eleventh week of foetal life while the two centres for the postsphenoid part, one on each side of the sella turcica, appear during the fourth month of intrauterine life and fuse together by the fifth month. The presphenoid

and the postsphenoid parts of the body fuse together about the eighth month of intrauterine life but even after birth for a short while the line of fusion is marked by the presence of a wedge-shaped cartilage at the lower part.

Lesser Wings. The lesser wings ossify from two centres, one for each wing which appear during the ninth week of intrauterine life at the lateral side of the optic foramen. The process of ossification spreads both ways and by the first year their medial extension fuse together above the anterior part of the body to form an elevated smooth swelling known as the ***jugum sphenoidale***.

Greater Wings. Each of the greater wings ossifies from two centres, one for its medial part which is preformed in cartilage and one for its lateral part which is preformed in membrane. Ossification begins in the medial part between the foramen rotundum and the foramen ovale by the eighth week of intrauterine life. Ossification in the lateral part also begins in the same time and extends downwards to form the lateral pterygoid plate. During the first year after birth the greater wing fuses with the body around the pterygoid canal. Two centres, one for each *lingula*, appear during the fourth month of intrauterine life and they soon fuse with the rest of the bone.

Medial pterygoid lamina. Each of the medial pterygoid plates except the pterygoid hamulus, develops in membrane and ossifies from one centre which appears during the ninth or tenth week of intrauterine life. The pterygoid hamulus is preformed in cartilage which ossifies during the third month of foetal life. The medial and the lateral pterygoid plates fuse together by the sixth month of the foetal life.

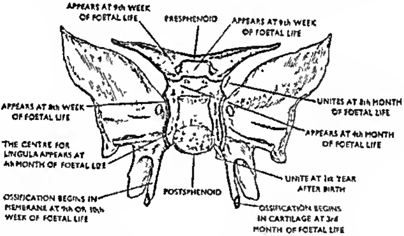


Fig. 394. The sphenoid bone at birth. Seen from behind.

Sphenoidal concha (*Bone of Berlin*). The sphenoidal concha begins to ossify during the fifth month of intrauterine life opposite the medial part of the cartilaginous cupula of the nasal capsule. At birth it is converted into bone either by extension of its single centre of ossification or by merging together of the different centres. During the fourth year the cartilaginous structure of the nasal capsule gets absorbed and this absorption extends to the lateral and back part of the bony concha, thus the nasal mucous membrane from which the future sphenoidal air sinus develops comes into relation with the presphenoid and during this period the bone remains ankylosed with the posterior aspect of the ethmoid. By the twelfth year the concha gets fused with the sphenoid.

Sphenoidal air sinus. Rudiments of the sinus appear during the third or fourth month of intrauterine life; at birth the sinus forms a distinct small cavity; at five years it is of considerable size and then grows continuously till puberty when it assumes its maximum size.

N. B. During foetal life between the presphenoidal and postsphenoidal parts a canal known as the *cranio-pharyngeal canal*, the remains of the original cleft at the base of the skull, extends downwards through the sella turcica. It is through this canal that a pharyngeal diverticulum known as the Rathke's pouch ascends upwards to form the anterior lobe of the pituitary body.

THE TEMPORAL BONE

The temporal bone occupies the sides as well as the base of the skull and contains the organ of hearing and bears an articular fossa for the attachment of the lower jaw. *Anatomically* it consists of *squamous, mastoid, petrous* and *tympanic parts* and the *styloid process*. *Morphologically* the temporal bone consists of *petromastoid, the squamous* and the *tympanic parts* and the *styloid process*. *Functionally* the petromastoid develops as a protective capsule, the cartilaginous capsule, around the membranous labyrinth of the internal ear; the squamous part develops in membrane as a superadded element in the lateral wall of the cranium to protect the larger brain in man. The tympanic part also develops in membrane as a ring of bone in connection with the external acoustic meatus and is specially designed to conduct the sound-wave in air medium. *Phylogenitically* the tympanic part is homologous with the *angular bone* of reptilians and the bony fishes in whom it forms a part of the composite lower jaw. The styloid process of the temporal bone is a derivative of the second visceral arch and has been integrated into it during its development.

Squamous part. The squamous part of the temporal bone forms the expanded, thin, translucent portion of the bone and is placed in between the greater wing of the sphenoid below and in front, and the inferior margin of the parietal bone above and behind. It consists of temporal and cerebral surfaces, a zygomatic process, an articular fossa, and superior and antero-inferior borders.

The TEMPORAL OR EXTERNAL SURFACE of the squamous part of the temporal bone forms the greater part of the temporal fossa and gives origin to the *temporalis muscle*. A vertical groove ascends upwards from opposite the upper part of the external acoustic (auditory) meatus and lodges the *middle temporal vessels*. A curved ridge known as the *supramastoid crest* ascends upwards and backwards from above the anterior part of the external acoustic (auditory) meatus and gives attachment to the *temporal fascia* and marks the posterior boundary of the temporal fossa. The line of fusion between the squamous and mastoid parts corresponds to a line about ½ an inch behind the supramastoid crest. The *auricularis posterior* muscle arises from the middle of the space between the supramastoid crest and the line of the squamo-mastoid suture. Between the anterior end of the supramastoid crest and the postero-superior sector of the external acoustic (auditory) meatus there is a triangular depression known as the *suprameatal triangle* which forms an important landmark for the tympanic antrum which lies at a depth of about ½ an inch from the surface. A bony projection on the medial side of the suprameatal triangle is known as the *suprameatal spine*.

The CEREBRAL OR INTERNAL SURFACE of the squamous part is concave and is marked by irregular impressions for the temporal gyri and presents grooves for the middle meningeal vessels. Inferiorly the cerebral surface joins with the petrous part and the remains of the petrosquamosal suture may be found in some adult bones.

The ZYGOMATIC PROCESS of the temporal bone forms an elongated bony process which articulates with the temporal process of the zygomatic bone and completes the zygomatic arch. It consists of two roots and an elongated thin anterior part. The roots of the zygomatic process are *anterior* and *posterior* and they converge to meet at a point to form a tubercle known as the *tubercle of the root of the zygoma* which gives attachment to the *temporomandibular ligament*. At the tubercle the process is twisted and the thin anterior part projects forwards from it. The *anterior root of the zygoma* projects horizontally lateralwards and its inferior surface is convex and smooth. It forms a thickened bar of bone in front of the articular fossa and is known as the

articular eminence. It articulates with the mandibular condyle by the intervention of an articular disc. In front of the articular eminence there is a small triangular area

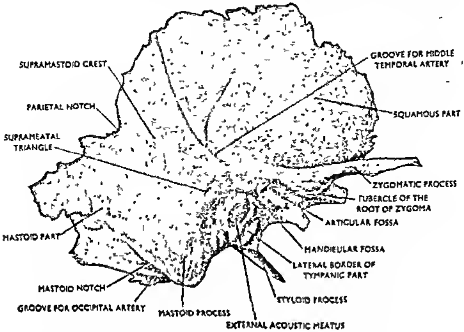


Fig. 395. The right temporal bone. External aspect.

which forms the roof of the infratemporal fossa. Anteriorly this triangular area limited by a ridge which is continuous behind with the anterior root of the zygo

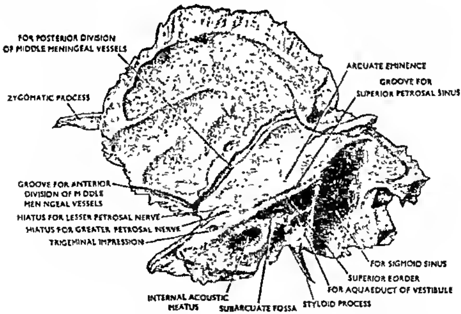


Fig. 396. The right temporal bone. Internal aspect.

and in front, in the articulated skull, with the infratemporal crest on the greater wi of the sphenoid. The *posterior root* inclines downwards and forwards and it is co tinuous behind with the supramastoid crest and in front with the superior border of t

thin anterior part of the zygoma. The thin *anterior part* of the zygomatic bone consists of a convex lateral surface and a concave medial surface, a thin superior border, an arched inferior border and a serrated anterior extremity. Its lateral surface is subcutaneous. Its medial surface close to its lower border gives origin to some of the fibres of the *masseter muscle.* The superior border gives attachment to temporal fascia, while the inferior border gives origin to the *masseter muscle.* The serrated anterior extremity articulates with the temporal process of the zygomatic bone and completes the zygomatic arch. Very rarely the squamous part of the temporal bone may present a foramen immediately above the anterior root of the zygomatic process and is known as the *squamosal foramen* which transmits the *petrosquamous sinus.*

MANDIBULAR FOSSA. The mandibular fossa of the temporal bone is formed partly by the squamous part and partly by the tympanic part. It consists of an *articular part* formed by the squamous part of the temporal bone and a *non-articular part* formed by the tympanic part of the bone. The articular part is deeply concave and is bounded in front by the convex articular emience and articulates with the condyle of the mandihle with an intervening articular disc to form the temporo-mandibular joint. The non-articular portion is occupied by a portion of the parotid gland. Laterally the articular part is separated from the non-articular or the tympanic part by a conical eminence known as the *postglenoid tubercle.* The postglenoid tubercle is well-developed in some mammals in whom it projects downwards behind the head of the mandible and thus prevents the backward displacement of the latter. Medially the articular part is separated from the tympanic part by a fissure known as the *squamotympanic fissure.* The downturned anterolateral portion of the tegmen tympani projects into this fissure and subdivides it into *petrotympanic* and *petrosquamosal fissures.* The petrotympanic fissure communicates with the tympanic cavity and lodges the *anteior ligament of the malleus* and transmits the *anterior tympanic branch of the maxillary artery.* The medial end of the petrotympanie fissure presents a small opening known as the *anterior canaliculus for the chroda tympani nerve* and gives exit to the same nerve.

The *superior border* of the squamous part articulates with the inferior border of the parietal bone. The *anteroinferior border* articulates with the greater wing of the sphenoid.

Mastoid part. The mastoid portion of the temporal bone occupies the posterior part of the temporal bone and is thicker in consistency than the squamous part. It presents an external surface, an internal surface, a mastoid process and superior and posterior borders.

The EXTERNAL SURFACE of the mastoid part is convex and antero-inferiorly it forms a conical projection known as the *mastoid process.* The external surface of the mastoid part including the mastoid proces, gives origin to *auricularis posterior* and *occipital belly of the occipito-frontalis* and insertion to *sternocleidomastoid, splenius capitis* and *longissimus capitis* in order from above downwards and forwards. The mastoid notch on the medial aspect of the mastoid process and the portion of the bone below it *gives origin to the posterior belly of the digastric muscle.* Below the digastric or mastoid notch the external surface is marked by a groove which lodges the *occipital artery.* Below the groove for the occipital artery and close to the posterior border there is a foramen, the *mastoid foramen,* which transmits an emissary vein connecting the sigmoid sinus with the posterior auricular vein and a *small branch of the occipital artery* which enters into the cramium to supply the duramater. The situation of the mastoid foramen is constantly variable.

The CEREBRAL OR INTERNAL SURFACE of the mastoid part is marked by a deep curved groove which lodges the *sigmoid sinus.* The mastoid foramen opens into its floor.

The *superior border* of the mastoid part is thick, short and serrated and articulates with the postero-inferior part of the parietal bone. It forms a notch with the superior border of the squamous part. Its *posterior border* is also thick and serrated and articulates with the inferior border of the occipital bone.

Section of the mastoid part. If we make a section through the mastoid par it is found to contain a number of irregular spaces known as the *mastoid air cells* Situated at its upper and anterior part and lying partly in the petrous part there is a large irregular space known as the ***mastoid*** **or** ***tympanic antrum.*** It is bounded in front by the epitympanic recess by means of which it communicates with the tympanic cavity behind by the mastoid air cells, laterally by that portion of the squamous part of the temporal bone which lies below the supramastoid crest (suprameatal triangle and medially by the lateral semicircular canal of the internal ear. The roof i formed by tegmen tympani.

Petrous part. The petrous part of the temporal bone forms a cylindrical pro cess of bone which is wedged between the greater wing of the sphenoid and the occ pital bone at the base of the skull. It consists of a base, an apex, three surfaces an three borders. Its surfaces are anterior, posterior and inferior and its borders ar superior, posterior and anterior. The base is fused with the squamous and th mastoid parts and the apex articulates with the petrosal process of the sphenoid. I is directed upwards, forwards and medially.

The ANTERIOR SURFACE of the petrous part is continuous with the cerebral surfac of the squamous part and is marked by irregular impressions for the temporal lobe o the brain. In the articulated skull it forms the part of the floor of the middle crani fossa. Immediately behind the apex this surface presents a depression known as th *trigeminal impression* and lodges the semilunar ganglion of the trigeminal nerve. The *greater superficial petrosal nerve* and the *motor root* of the *trigeminal ganglion* intervene between the floor of the trigeminal impression and the ganglion. Behind the trigeminal impression and separated from it by an irregular ridge is a second hollow or depressed area which roofs in the internal auditory meatus and covers the cochlea. Behind this there is an irregular eminence known as the *arcuate eminence* and is formed by the superior semicircular canal of the internal ear. Its lateral part overlies the vestibule and the facial canal whereas its posterior part is formed by the posterior and lateral semicircular canals of the internal ear. Between the arcuate eminence and the two hollows on the medial side and the squamous part on the lateral side there is a thin plate of bone known as the *tegmen tympani* which forms the roof of the tympanic antrum, tympanic cavity and the canals for the tensor tympani and the auditory (pharyngotympanic) tube. Laterally the tegmen tympani is bent on itself and descends downwards on the medial side of the squamous part and forms the lateral wall of the auditory tube. Its antero-lateral portion projects into the squamotympanic fissure. On the anterior part of the tegmen tympani there is a faint groove which leads posteriorly into an opening, *the hiatus for the greater superficial petrosal nerve* and transmits the same nerve. Lateral to this hiatus there is another foramen which transmits the *lesser superficial petrosal nerve* from the tympanic plexus.

The POSTERIOR SURFACE is continuous with the inner surface of the mastoid portion and forms the anterior part of the posterior cranial fossa in the articulated skull. Opposite to the middle of this surface there is a *circular aperture* which leads into a canal, the *internal acoustic (auditory) meatus* which extends laterally for about 1 cm. It gives entrance to the *facial nerve* and the *internal auditory artery*, branch of the posterior cerebellar or basilar artery, and exit to the *statoacoustic (auditory) nerve* and the internal auditory vein which ends in the inferior petrosal sinus. Behind this is a slit under cover of a thin plate of bone which leads to the aqueduct of vestibule and lodges the *saccus* and the *ductus endolymphaticus together with a small vein and an artery.* Above and between these two openings and situated more on the superior border is an irregular depression known as the *subarcuate fossa* which transmits a small vein and lodges a process of duramater.

Internal auditory meatus. It is a short, roughly horizontal or transverse canal measuring about 1 cm. or 10 mm. in length and from 3 to 5 mm. in diameter and is situated in the middle of the posterior surface of the petrous part of the temporal bone. At the lateral end of the canal is a perforated plate of bone which constitutes its bottom or the *fundus* and forms the medial wall of the internal ear and is situated

roughly opposite the external acoustic (auditory) meatus. It gives entrance to the motor root of the facial nerve and the internal auditory artery, a branch of either basilar or the posterior cerebellar artery, and exit to sensory root of the facial nerve, the stato-acoustic (auditory) nerve, and the internal auditory vein which terminates into the inferior petrosal sinus.

The bottom or the fundus of the internal auditory meatus is a perforated plate of bone and presents a transverse crest which divides it into an upper and a lower area. In the anterior part of the upper area there is large single opening, the commencement of the facial canal, for the transmission of the facial nerve. The area posterior to this is called the *superior vestibular area* in which there are numerous small foramina for the transmission of the nerves to the utricle and to ampullae of the superior and lateral semicircular ducts. The anterior part of the inferior or the lower area is called the *cochlear area* which corresponds with the base of the cochlea. In the cochlear area there is a *central canal* around which there is a spiral tract with foramina known as the *tractus spiralis foraminosus;* the former transmits the nerves to the apical coil of the cochlea while latter transmitting the nerves for the rest of the cochlea (basal and middle coils). Behind the cochlear area is the *inferior vestibular area* which is perforated by foramina for transmission of the nerves of the saccule. Behind the inferior vestibular area is foramen, the *foramen singulare* which transmits the nerves to the ampula of the posterior semicircular duct.

Facial canal. The facial canal begins from the anterior part of the superior fossa at the bottom of the internal auditory meatus in front of the superior vestibular area. It then passes forwards and laterally for a distance of 1.5 to 2.0 mm. above the vestibule of the internal ear and reaches the medial wall of the tympanic cavity and then turns abruptly backwards (the genu) and runs in a horizontal ridge on the medial wall of the tympanic cavity. At the point where it turns abruptly backwards the canal becomes dilated to accommodate the geniculate ganglion. In the tympanic cavity it lies in the angle between its medial wall and the tegmen tympani and immediately above the fenestra vestibuli and extends as far backwards as the medial wall of the epitympanic recess (through which the tympanic cavity communicates with the tympanic antrum) and lies immediately below and in contact with the bony canal for the lateral semicircular canal. The facial canal then turns downwards and lies in the angle between the medial and posterior walls of the tympanic cavity and finally it terminates at the stylomastoid foramen.

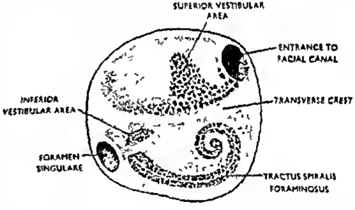


Fig. 397. The bottom of the internal acoustic meatus.

The canal is traversed by the facial nerve and its walls present numerous foramina for the passage of the branches of the facial nerve and other nerves communicating with it. At the genu the canal presents a foramen through which the greater superficial petrosal nerve exits and a branch from the middle meningeal artery enters into it. In the vertical part of its course it presents another opening which pierces through pyramidal eminence and close to it there lies the opening for the auricular branch of the vagus which communicates with the facial nerve. Close to its termination at the stylomastoid foramen the canal is pierced by the opening of the posterior canaliculus for the chorda tympanic nerve.

The INFERIOR SURFACE of the petrous part is irregular and is outside the cranial cavity and looks downwards. Close to the apex is a quadrilateral rough area which is divided into upper, middle and lower parts: the upper part gives origin to *levator palati muscle*; the middle area is in contact with the cartilaginous portion of the pharyngo-tympanic tube; the lower area forms an articular edge which articulates with the basilar part of the occipital bone by means of some dense fibrous tissue. Behind the quadrilateral area is a circular opening, the *lower opening of the carotid canal* and transmits internal carotid artery with its plexus of sympathetic nerves. Behind the carotid opening is a deep depression known as the *jugular fossa* and lodges the superior bulb of the internal jugular vein. On the ridge separating the jugular

fossa and the carotid opening is a small aperture known as the *tympanic canaliculus* and transmits the tympanic branch of the glossopharyngeal nerve. Immediately below the internal auditory meatus and in front of the medial part of the jugular fossa is a *triangular depression* which lodges the inferior ganglion of the glossopharyngeal nerve. At its apex there is a foramen which communicates with the cochlear canaliculus and lodges the aqueduct of the cochlea and a process of dura mater and transmits a small vein from the cochlea which opens into the internal jugular vein.

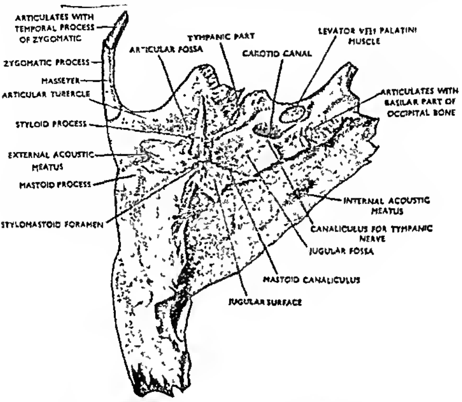


Fig. 398. The right temporal bone. Inferior aspect.

Through the aqueduct of the cochlea the perilymph of the labyrinth is enabled to drain into the sub-arachanoid space. Behind the jugular fossa is a small quadrilateral articular surface known as the *jugular surface* and articulates with the jugular process of the occipital bone. On the lateral wall of the jugular fossa is a minute foramen, the *mastoid canaliculus* which transmits the auricular branch of the vagus nerve. Behind the jugular surface is a slender process of bone known as the *styloid process* which projects dawnwards and ends in a pointed extremity. It measures about an inch in length and gradually narrows from its base to its apex. It gives origin to the styloid group of muscles and attachment to the stylohyoid and stylomandibular ligaments. The styloid group of muscles are styloglossus, stylohyoid and stylopharyngeus. The *styloglossus* arises from its anterior aspect close to its tip, the *stylohyoid* arises from middle of its posterior-aspect and the stylopharyngeus arises from its medial aspect close to its base. The *stylohyoid ligament* is attached to its tip. Its lateral aspect gives attachment to the stylomandibular ligament. The stylohyoid and the stylomandibular ligaments are formed by the deep cervical fascia. Lateral to the styloid process is a curved plate of bone formed by the tympanic part which forms a sort of sheath for the styloid process and is known as the *sheath* of the *styloid process*. Behind the styloid process is a foramen, the *stylomastoid foramen* which gives exit to the facial nerve and entrance to the stylomastoid branch of the posterior auricular artery.

The *superior border* of the petrous part is its longest border and presents a narrow groove which lodges the *superior petrosal sinus* and the margins of the groove give attachment to the *tentorium cerebelli.* The *posterior border* is smaller than the superior border but larger than the anterior border. It presents a partial groove which forms a complete one with a similar groove on the basilar part of the occipital bone and lodges the *inferior petrosal sinus.* The *anterior border* is divided into two parts, a lateral and a medial part; the lateral part joins with the squamous part at the petro-squamosal suture and its medial part articulates with the greater wing of the sphenoid.

Tympanic part. The tympanic part of the temporal bone forms a plate of bone in the adult which is interposed between the squamous and the mastoid parts. In front it joins with the squamous part at the squamotympanic fissure, and behind, it joins with the mastoid process at the tympano-mastoid fissure through which the *auricular branch of the vagus nerve* comes out. Internally it is fused with the petrous part of the temporal bone. It consists of two surfaces and three borders.

The *anterior surface* is more or less quadrilateral in shape and is gently concave. It forms the posterior non-articular part of the mandibular fossa and lodges a portion of the parotid gland.

The *posterior surface* is concave and forms the greater part of the circumferential boundary of the external acoustic (auditory) meatus. It forms the anterior and part of the posterior wall and the floor of the external acoustic (auditory) meatus. The medial part of this surface is marked by a circular sulcus, the *tympanic sulcus,* which gives attachment to the tympanic membrane.

The *lateral margin* of the tympanic part forms the circumferential margin of the bony external ear and gives attachment to the cartilaginous part of the external ear. Its *superior border* meets with the squamous part medially at the squamotympanic fissure and with the postglenoid tubercle laterally. Its *lower border* extends from the carotid canal to the styloid process. The lateral part of this border ensheathes the styloid process and is known as the *sheath* of the *styloid process.*

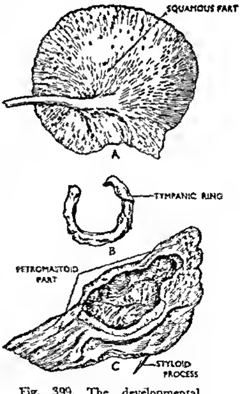


Fig. 399. The developmental parts of the temporal bone.

Ossification. Developmentally the temporal bone consists of 4 parts namely, *squamosal, tympanic, petro-mastoid* and *hyal.* The squamosal and the tympanic parts develop in membrane while the petrosal and hyal parts develop in cartilage. At birth the four elements of the bone are easily separable from one another and the squamosal part represents the squama, zygomatic process and a small portion of the mastoid, the tympanic part representing the incomplete tympanic ring, the petrosal part representing the petrous and mastoid parts, and the hyal part representing the styloid process; the tympanic part being represented only by the incomplete ring the bony external auditory meatus is not formed and the tympanic membrane lies only on the surface of the bone; the mastoid process has not formed and the styloid process is cartilaginous except its embedded portion which is bony. The bone gradually develops in the process of ossification from the following centres of ossification.

Squamosal part. This part ossifies in membrane from one centre which appears

during the later part of the second month of intrauterine life at the root of the zygomatic process and from these the ossification proceeds forwards to the zygomatic process, upwards to the squamosal part, medialwards to the articular part of the mandibular fossa and downwards and backwards to form the lateral wall of the tympanic antrum and the antero-superior part of the mastoid. The portion of bone which grows downwards and backwards below the supramastoid crest from the squama is called the *postauditory process*.

Tympanic part. This also ossifies in membrane and the process of ossification starts as early as the third month of intrauterine life. At birth it forms an incomplete ring (5/6 of a circle) the extremities of which are ankylosed to the squamous part. The future tympanic plate is formed by outward growth of the tympanic ring which also results in the formation of the bony external auditory meatus.

Petrosal part. The petrosal part develops in cartilage and ossifies from four centres, *opisthotic, pro-otic, pterotic* and *epiotic,* which appear during the fifth month of intrauterine life.

Opisthotic centre. This centre appears first of all and extends from the promontory on the medial wall of the tympanic cavity and forms the floor of the tympanic cavity and the internal auditory meatus and part of the medial wall of the tympanic cavity together with the floor of the vestibule and most of the bony cochlea and the carotid canal.

Pro-otic centre. This centre of ossification appears in the region of arcuate eminence and from it are formed the bony superior semicircular canal, roof of internal auditory meatus, vestibule and the cochlea and a portion of the mastoid part, in fact, the whole mass of bone on the anterior surface of the petrous part extending from the apex to the mastoid part develops from its centre.

Pterotic. This is a small centre which gives rise to the formation of bony lateral semicircular canal and the tegmen tympani.

Epiotic. This centre forms the greater part of the mastoid and the bony posterior semicircular canal.

Hyal part. The hyal part or the styloid process develops from the cranial end of the second arch cartilage and ossifies from two centres, *tympano-hyal* and *stylohyal.* The tympanohyal centre appears during the later part of intrauterine life and forms the basal part of the process which is embedded within and soon fuses with the tympanomastoid. The stylohyal centre appears during the first or the second year of life and forms that portion of the process which projects outside. The tympanohyal and the stylohyal parts are fused together nearly during middle life.

THE ETHMOID BONE

The ethmoid bone is situated in the anterior part of the cranium below the ethmoidal notch of the frontal bone. It is exceedingly light and fragile in consistency. In the articulated skull it forms the *roof, lateral wall* and the *septum of the nose, medial wall of the orbit* and *part of the floor of the anterior cranial fossa.* It consists of a horizontal *cribriform plate,* two *lateral masses* or *labyrinths* which are joined together by the cribriform plate and a *perpendicular plate* which descends downwards from the undersurface of the cribriform plate.

Cribriform plate. The cribriform plate is so named because it is perforated by numerous foramina and is comparable to a seive. It fills up the ethmoidal notch of the frontal bone and joins on either side with the labyrinth or the lateral mass. It has an upper and a lower surface and four borders, namely, anterior, posterior and two lateral. A smooth triangular process known as the *crista galli* (having its resemblance to a cock's comb) projects upwards from the anterior part of the superior surface opposite the median plane. Anteriorly the crista galli forms two projecting alae which articulate with the frontal bone and completes the *foramen caecum* which transmits an emissary vein connecting the superior sagittal sinus with the veins of the

nasal fossa. Posteriorly its free border gives attachment to the anterior part of the falx cerebri. On its either wall it forms a bulging due to a contained air cell within. On either side of the crista galli the superior surface presents a narrow depressed area which lodges the gyrus rectus and the olfactory tract and is perforated by series of foramina which are arranged in three rows—lateral, medial and intermediate. The lateral group of foramina transmit the olfactory nerves from the lateral wall of the nasal cavity, the medial group transmitting the olfactory nerves from the septum of the nose and the intermediate group transmit the nerves from the roof of the corresponding nasal cavity. On each of the side of the anterior end of the crista galli there is a slit-like aperture which lodges a process of dura mater. Lateral to this there is a

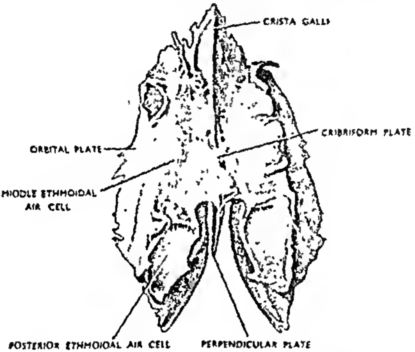


Fig. 400. The ethmoid bone. Viewed from above and behind.

small foramen which transmits the anterior ethmoidal vessels and nerves. A faint groove passes backwards from this foramen along the upper surface of the labyrinth to meet a transverse groove on the same surface. When the labyrinth articulates with the ethmoidal notch of the frontal bone this transverse groove together with a similar groove on the margin of the ethmoidal notch of the frontal bone is converted into a canal, known as the anterior ethmoidal canal. The *posterior border* of the cribriform plate articulates with the ethmoidal spine of the sphenoid bone. The perpendicular plate of the ethmoid descends downwards from opposite the median plane of its inferior surface. On either side of the median plane its inferior surface forms the roof of the corresponding nasal cavity. Its *lateral margins* fuse with the labyrinth on either side. Its *anterior border* is occupied by the projecting alae of the crista galli.

Perpendicular plate. The perpendicular plate of the ethmoid is a thin, quadrilateral piece of bone that projects downwards from the undersurface of the cribriform plate. It forms the main part of the bony septum between the two nasal cavities and consists of four borders. The *anterior border* is slightly oblique in direction and articulates with the nasal spine and the crest formed by the two nasal bones. The *posterior border* articulates with the sphenoidal crest above and with the vomer below. Its *inferior border* gives attachment to the septal cartilage of the nose. The *superior border* fuses with the undersurface of the cribriform plate. Its surfaces are lined by muco-periosteum and its upper part presents a series of short grooves

which lodge the olfactory nerves that pass through the medial group of foramina on the cribriform plate.

Labyrinth. The labyrinth or the lateral mass of the ethmoid consists of two vertical plates of bone and interposed between them are the three groups of thin walled ethmoidal air cells—*anterior*, *middle* and *posterior*.

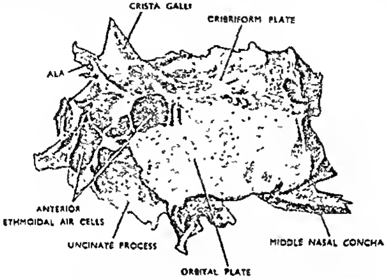


Fig. 401. The ethmoid bone. Viewed from the left side.

Each labyrinth has six surfaces, namely, anterior, posterior, superior, inferior, lateral and medial. The *anterior surface* of the labyrinth articulates with the frontal process of the maxilla and the lacrimal bone. The *posterior surface* articulates with the sphenoidal concha. The *superior surface* articulates with the margins of the ethmoidal notch of the frontal bone. The *inferior surface* articulates with the orbital surface of the maxilla in front and the orbital process of the palatine bone behind. The *lateral surface* is formed by the lateral plate and is thin, smooth and quadrilateral in shape and is better known as the *orbital plate* because it forms the medial wall of the orbital cavity.

The *orbital plate* articulates in front with the lacrimal bone, behind with the sphenoidal concha, below with the medial margin of the orbital surface of the maxilla in front and the orbital process of the palatine bone behind.

The *medial surface* of the labyrinth is formed by a vertical plate of bone which descends almost parallel to the perpendicular plate. It descends vertically downwards and ends below into a convoluted or curved margin with a concavity on the lateral side. The convoluted portion of the bone is known as the *middle nasal concha* whereas the concave space on its lateral side constitutes the *middle meatus of the nose*. Descending downwards and backwards from the anterior end of the labyrinth and projecting into the middle meatus of the nose is a thin curved piece of bone known as the *uncinate process* which articulates with the ethmoidal process of the inferior nasal concha and helps in the closure of the maxillary air sinus. A rounded swelling projects into the middle meatus from the medial side and is known as the *bulla ethmoidalis* and is caused by the middle ethmoidal air cell. The *middle* and the *anterior ethmoidal air cells, the maxillary air sinus and the frontal air sinus open into the middle meatus of the nose*. The frontal air sinus opens into it through fronto-nasal duct via the infundibulum.

At the posterior end of the labyrinth there is a fissure known as the *superior meatus of the nose* which is bounded above by a curved thin plate of bone known as the *superior nasal concha*. The *posterior ethmoidal air sinus* opens into the superior meatus. The *sphenoidal air sinus* also opens into it at the spheno-ethmoidal recess.

Ossification. The ethmoid bone develops in cartilage from the cartilaginous nasal capsule. It ossifies from three centres, one for each of the labyrinths and one for perpendicular plate. During the fifth month of intrauterine life ossification begins in the region of the orbital plate and then extends downwards and inwards to form the superior and medial nasal conchae and at birth the labyrinth becomes almost osseous. During the first year of life ossification begins in the perpendicular plate in the region of the crista galli and from this the ossification spreads upwards into

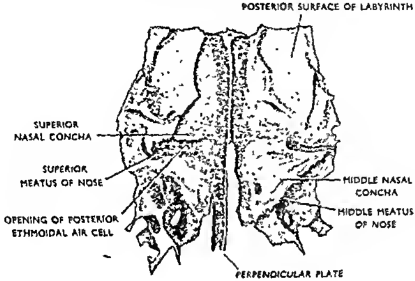


Fig. 402. The ethmoid bone. Viewed from below and behind.

the crista galli, downwards into the perpendicular plate and sidewards into the cribriform plate. Extension of ossification from the labyrinth medialwards also helps to form the cribriform plate, thus the cribriform plate is formed by extension of ossification both from the labyrinth as well as from the perpendicular plate. The two labyrinths and the perpendicular plate fuse together during the fifth year of life. The ethmoidal air sinuses begin to form during intrauterine life and by the third year of life they acquire osseous boundary.

THE LACRIMAL BONE

The lacrimal bone is the smallest and most fragile of all the cranial bones and lies in the anterior part of the medial wall of the orbit. It consists of lateral and medial surfaces and anterior, posterior, superior and inferior borders. Its *lateral surface* presents a ridge known as the *posterior lacrimal crest* which ends below into a hook-like bony projection called the *lacrimal hamulus*. *In front of the posterior lacrimal crest* there is a *vertical groove*, the lower part of which descends downwards beyond the rest of the bone and is known as the *descending process*. Its *medial surface* presents a vertical groove corresponding to the ridge on the lateral surface and this groove divides the medial surface into a smaller anterior part and a larger posterior part. All of its borders are articular.

The posterior lacrimal crest gives attachment to the lacrimal fascia throughout its whole length and close to its middle part it gives origin to the *lacrimal head of the orbicularis oculi*. The groove in front of the crest is roofed by the *lacrimal fascia* which passes forwards to be attached to the anterior lacrimal crest on the frontal process of the maxilla. This groove together with the vertical groove behind the anterior lacrimal crest of the frontal process of the maxilla forms a shallow groove, the *fossa for the lacrimal sac* which lodges the *lacrimal sac*. The lower part of the groove is prolonged downwards along the descending process and forms a part of the nasolacrimal canal which transmits the *nasolacrimal duct*. The portion of the

lateral surface behind the crest forms the anterior part of the medial wall of the orbit. The lacrimal hamulus completes the lateral boundary of the upper opening of the nasolacrimal canal. The lacrimal hamulus sometimes exists as a separate bone and is known as the *lesser lacrimal bone.*

The area in front of the vertical groove on the medial surface forms a part of the middle meatus of the nose while the area behind it covers the anterior ethmoidal air cells.

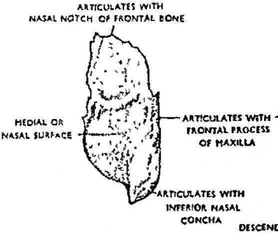


Fig 403 The left lacrimal bone; internal aspect

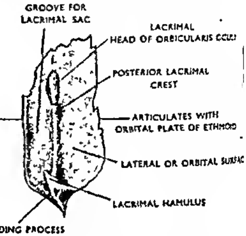


Fig. 404. The left lacrimal bone; external aspect.

Articulations. (1) Its *anterior border* articulates with the posterior border of the frontal process of the maxilla. (2) Its *posterior border* articulates with the anterior border of the orbital plate of the ethmoid. (3) Its *superior border* articulates with the nasal notch of the frontal bone. (4) Its *inferior border* articulates with the medial margin of the orbital surface of the maxilla. (5) The descending process by its tip articulates with the lacrimal process of the inferior nasal concha and by its margins with the margins of the nasolacrimal groove. (6) The lacrimal hamulus by its tip articulates with the lacrimal tubercle on the orbital margin of the maxilla.

Side determination. Hold the bone in such a way that the groove on the lateral surface lies in front of the ridge. The descending process projects downwards or the lacrimal hamulus projects forwards and medially from the lower part of the ridge and the latter will determine the side to which the bone belongs.

N. B The lacrimal fascia is nothing but the orbital periosteum which after being attached to the posterior lacrimal crest bridges over the lacrimal groove and is attached anteriorly to the anterior lacrimal crest on the frontal process of the maxilla.

Ossification. The lacrimal bone develops in membrane and ossifies from one centre which appears during the third month of intrauterine life.

THE INFERIOR NASAL CONCHA

The inferior nasal conchae are two curved laminae of bones, each of which occupies the lateral wall of the corresponding nasal cavity. Each bone consists of two surfaces, two borders, two ends and three processes. Its surfaces are medial and lateral, borders are superior and inferior, ends are anterior and posterior and processes are lacrimal, ethmoidal and maxillary.

The *medial surface* is convex and is marked by numerous vascular foramina. The *lateral surface* is concave. The *superior border* is articular both in front and behind and in the intermediate portion it holds three processes—*lacrimal, ethmoidal* and *maxillary.* The anterior articular portion of the superior border articulates with the

conchal crest of the maxilla. The posterior articular portion articulates with the conchal crest of the palatine bone. The *lacrimal process* is projecting upwards immediately behind the anterior articular portion and articulates with the descending process of the lacrimal bone by its tip and by its margin with the margins of the

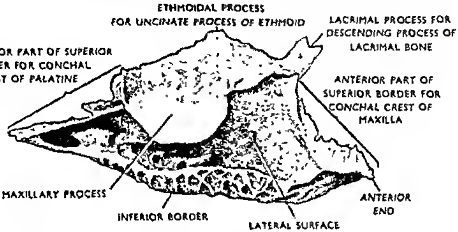


Fig. 405. The lateral aspect of right inferior nasal concha.

nasolacrimal groove. The *ethmoidal process* lies behind the lacrimal process and forms an irregular process which projects upwards and articulates with the uncinate process of the ethmoid bone. The *maxillary process* curves on the lateral surface and closes a considerable portions of the maxillary air sinus; by its anterior margin it articulates with the margin of the maxillary air sinus and by its posterior margin it articulates with the maxillary process of the palatine bone. The inferior border is non-articular and rounded. Both the ends are pointed but the posterior end is more tapering. Both the surfaces of the inferior nasal concha are covered by muco-periosteum.

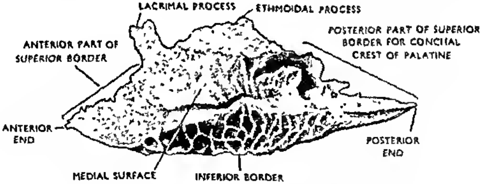


Fig. 406. The medial aspect of the right inferior nasal concha.

Side determination. Hold the bone in such a way that its more tapering posterior end looks backwards, the superior border carrying processes looks upwards, the lacrimal process projects upwards from the anterior part of the intermediate portion and the concave lateral surface will determine the side to which the bone belongs.

Ossification. The inferior nasal concha develops in cartilage from the incurved lower border of the lateral wall of the cartilaginous nasal capsule. It begins to ossify from one centre during the fifth month of intrauterine life and as the process of ossification continues it becomes separated from the cartilaginous nasal capsule. and forms the individual bone.

THE NASAL BONE

The nasal bones are two small bones which are placed side by side between the frontal processes of the two maxillae and by their articulation form the bridge of the nose. They vary in size and form and are responsible for the general contour of the nose. Each nasal bone has an external and an internal surface, and a medial, a lateral, a superior and an inferior border.

The *external surface* is smooth and concavo-convex and is covered by procerus and compressor naris. It presents a foramen near its centre for the exit of a vein from the nasal fossa. The *internal surface* is concave and is traversed by a groove which passes from above downwards and lodges the anterior ethmoidal nerve.

The *superior border* is the thickest and the shortest of all and is articular. It articulates with the nasal notch of the frontal bone. The *inferior border* is very thin and articulates with the lateral cartilage of the nose. It presents a notch which is converted into a foramen by articulation with the lateral cartilage of the nose and transmits the external nasal nerve. Its *medial border* is thicker above than below and its upper part projects backwards as a thin edge. It articulates with the fellow of its opposite side and forms a crest which projects backwards and articulates, from above downwards, with the nasal spine of the frontal bone, perpendicular plate of the ethmoid and the septal cartilage of the nose. Its *lateral border* articulates with the frontal process of the maxilla.

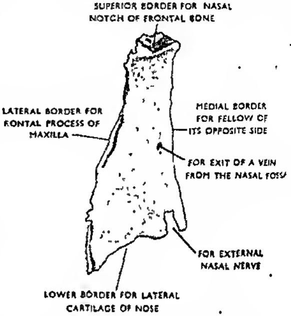


Fig. 407. The external aspect of right nasal bone.

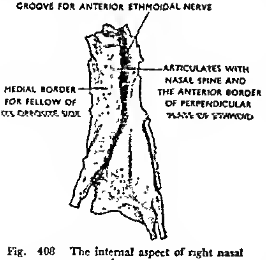


Fig. 408 The internal aspect of right nasal bone.

Side determination. Hold the bone in such a way that the thickest and the shortest superior border looks upwards, the thick medial border looks medially and the projecting edge from its upper part looks backwards and the concavo-convex, smooth lateral surface will determine the side to which the bone belongs.

Ossification. Each nasal bone develops in membrane and ossifies from one centre which appears during the third month of intrauterine life.

THE VOMER

The vomer is a thin, flat and an irregularly quadrilateral-shaped bone which occupies the median plane and forms a part of the bony nasal septum. It consists of four borders, two surfaces and a pointed end. Its borders are superior, inferior, anterior and posterior. On either side its surfaces form the medial wall of the corresponding nasal cavity.

The *superior border* is broad and expanded and splits into two projecting alae. Between the two projecting alae it forms a fissure which articulates with the rostrum of the sphenoid and the articulation thus formed is a variety of fibrous joint and is known as *schindylesis*. The margin of each projecting ala articulates from before backwards with the sphenoidal concha, sphenoidal process of the palatine bone and with the vaginal process of the medial pterygoid lamina of the sphenoid. The *inferior border* articulates with the nasal crest formed by the two maxillae and the

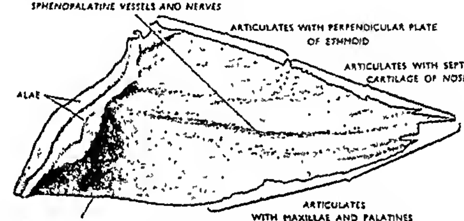


Fig. 409. The vomer. Seen from the right side.

two palatine bones. The *anterior border* articulates with the perpendicular plate of the ethmoid above and with the septal cartilage of the nose below. The *posterior border* is short and non-articular and forms the medial boundary of the posterior nasal aperture. The tip or the pointed apex of the vomer fits into the incisor crest of the maxillae and divides the incisive canal into two compartments. Each of its surfaces is marked by a longitudinal groove for the nasopalatine (long sphenopalatine) vessels and nerves.

Ossification. The vomer develops in membrane which surrounds the postero-inferior part of the cartilaginous septum during intrauterine life. It ossifies from two centres which appear during the eighth week of foetal life, one on each side of the median plane. During the third month of intrauterine life the two centres fuse together below the cartilaginous septum and thus a bilaminar bone is formed which ensheathes the cartilaginous septum. Later on as the process of bone formation continues upwards and forwards the enclosed cartilaginous septum gets absorbed and the two laminae become fused together during puberty.

THE MAXILLA

Except the mandible the maxilla is the largest bone of the face and the two maxillae by their articulation form the whole of the upper jaw, three-fourths of the hard palate, greater part of the floor of the orbit, greater part of the floor and lateral wall of the nasal cavity and part of the bridge of the nose. In the articulated skull it also forms the infratemporal and pterygopalatine fossae and the pterygomaxillary and the infraorbital fissures. It consists of a body and four processes namely frontal, zygomatic, palatine and alveolar.

The BODY of the maxilla is large and pyramidal in shape and contains a large air sinus known as the *maxillary air sinus*. It consists of *anterior*, *infratemporal (posterior)*, *orbital* or *superior* and *nasal* or *medial surfaces*.

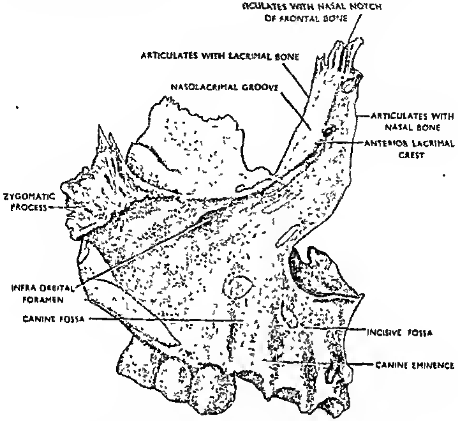


Fig. 410. The right maxilla. Anterior surface Seen from the front.

The *anterior surface* faces forwards and lateralwards and is separated from the posterior surface by an indistinct ridge which ascends upwards from the root of the second molar tooth. The lower part of the anterior surface is marked by a series of ridges formed by the sockets of the upper teeth. Above the sockets of the two anterior teeth (incisor teeth) there is a fossa, the *incisive fossa*, which gives origin to the depressor septi and close to the alveolar border to some of the fibres of the orbicularis oris. Above and lateral to this fossa the anterior surface gives origin to compressor naris. Behind the incisive fossa and separated from it by an eminence (canine eminence) is the *canine fossa* which gives origin to levator anguli oris muscle. Above the canine fossa is the *infraorbital foramen* which transmits the infraorbital vessels and nerves. Above this foramen and between it and the infraorbital margin it gives origin to levator labii superioris. Anteromedially the anterior surface is separated from the medial surface by a thin concave margin known as the *nasal notch*, the margin of which gives origin to dilator naris. The nasal notch ends anteriorly in a pointed bony projection which together with the fellow of its opposite side forms the *anterior nasal spine*.

The *infratemporal surface* (*posterior surface*) is convex in its general outline and is directed backwards and laterally. It forms the anterior boundary of the infratemporal fossa, and near the centre, this surface is perforated by two or three small foramina, the *alveolar canals*, for the entrance of the posterior superior dental vessels and nerves. Close to its postero-inferior angle this surface presents a rough articular area known as the *maxillary tuberosity* which articulates with the pyramidal process (tubercle) of the palatine bone. A little below its postero-superior angle there is a

shallow curved groove which is continued on to the orbital surface and transmits the maxillary nerve. This smooth portion of the infratemporal surface containing the groove for the maxillary nerve forms a part of the anterior wall of the pterygopalatine fossa. Opposite to the middle of the posterior border of the posterior surface is the upper end of a vertical groove, the *greater palatine groove*, which transmits the greater palatine vessels and nerves. The posterior surface forms the anterior wall of the infratemporal fossa and its upper smooth portion also forms the aoterior boundary of the pterygopalatine fossa.

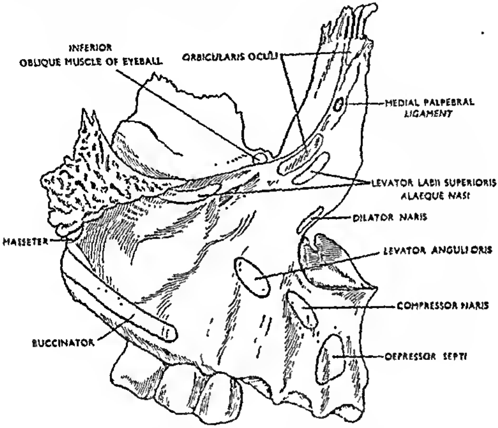


Fig. 411. The right maxilla. Anterior surface. Showing attachments.

The *orbital surface* is more or less triangular in shape aod forms the greater part of the floor of the orbit. It is separated from the anterior surface by the rounded infraorbital margin. It is separated from the infratemporal (posterior) surface by a rouoded margin which forms the lower boundary of the inferior orbital fissure. Opposite to the middle of this margin is a groove or notch from which the infraorbital canal begins and traverses through the orbital surface to end into the infraorbital foramen on the anterior surface and transmits the infraorbital vessels and nerves. Its medial margin separates it from the nasal surface and anteriorly this margio is separated from the frontal process by a vertical notch, the *nasolacrimal notch*, which is converted into the nasolacrimal canal by the descending process of the lacrimal bone and transmits the nasolacrimal duct. The medial margin behind the nasolacrimal notch articulates from before backwards, with the lacrimal bone, the orbital plate of the ethmoid and the orbital process of the palatine bone. The orbital surface at its antero-medial aogle immediately lateral to the nasolarcimal groove presents a small depression from which the inferior oblique muscle of the eye ball arises.

The NASAL SURFACE of the body of the maxilla presents a large opening at its upper and posterior part known as the *maxillary hiatus* which leads into the *maxillary air sinus*. Above the opening of the maxillary hiatus there are a few broken

air-cells which are completed by the labyrinth of the ethmoid and by the lacrimal bone. Below it the medial or nasal surface forms a part of the inferior meatus of the nose. In front of the hiatus is the nasolacrimal groove which is converted into nasolacrimal canal by the articulation of the descending process of the lacrimal bone with the lacrimal process of the inferior nasal concha. In front of the nasolacrimal groove the medial surface presents an oblique ridge known as the *conchal crest of the maxilla* which articulates with the anterior part of the superior border of the inferior nasal concha. Above the conchal crest a shallow depressed area

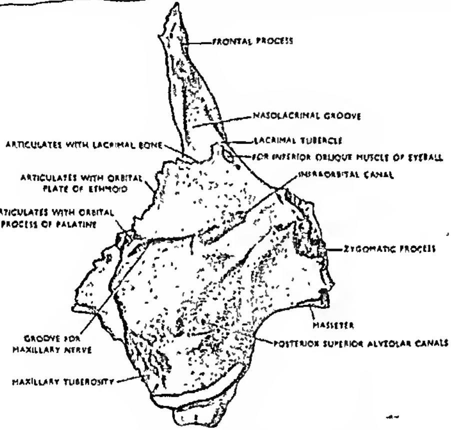


Fig 412 The right maxilla. Seen from behind.

forms a part of the atrium of the middle meatus of the nose and below it the rest of the surface forms part of the inferior meatus of the nose. Behind the maxillary hiatus the medial surface forms a rough area which articulates with the perpendicular plate of the palatine bone. Traversing this rough area is a vertical groove, *the greater palatine groove*, which is converted into the greater palatine canal with a similar groove on the lateral surface of the perpendicular plate of the palatine bone and transmits the greater palatine vessels and nerves. The maxillary hiatus in the articulated skull is much reduced in size and two small foramina of unequal size are left behind, one of which remains closed in the recent state by a mucous plug and the other opens into the middle meatus of the nose. *Bones reducing the size of the maxillary hiatus* are the uncinate process of the ethmoid articulating with the ethmoidal process of the inferior nasal concha, the maxillary process of the inferior nasal concha articulating with the maxillary process of the palatine bone and most posteriorly by the perpendicular plate of the palatine bone.

Frontal process. The frontal process of the maxilla projects upwards from the upper and anterior part of the junction of the anterior and medial surfaces. It consists of lateral and medial surfaces, anterior and posterior borders and an

upper end. The lateral surface presents a vertical ridge which is continuous below with the infraorbital margin and is known as the *anterior lacrimal crest*. It gives attachment to the lacrimal fascia and the medial palpebral ligament. The area in front of the lacrimal crest gives origin to orbicularis oculi and to levator labii superioris alaeque nasi. The area posterior to the lacrimal crest forms a groove which together with a similar groove on the lacrimal bone forms the *lacrimal groove* which lodges the lacrimal sac. At the junction of the lacrimal crest with the orbital margin there is a small tubercle which articulates with the lacrimal hamulus and forms a guide

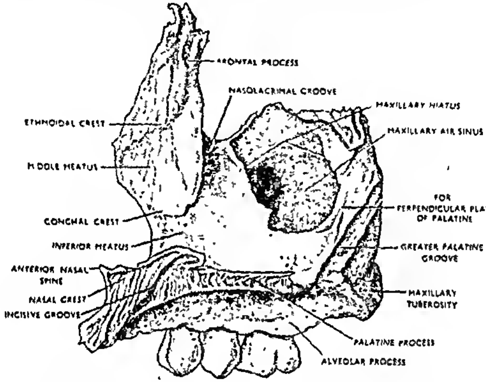


Fig. 413. The right maxilla. The nasal or the medial aspect.

to the lacrimal sac. The medial surface of the frontal process of the maxilla presents a short, transverse ridge immediately below the upper end, known as the *ethmoidal crest*. The posterior part of the ethmoidal crest articulates with the superior nasal concha whereas its anterior part forms the agar nasi. The rough area above the ethmoidal crest articulates with the anterior aspect of the labyrinth of the ethmoid and completes the anterior ethmoidal air cells. The portion below the ethmoidal crest forms a shallow depressed area which forms the atrium of the middle meatus of the nose. The anterior border articulates with the lateral border of the nasal bone whereas the posterior border articulates with the anterior border of the lacrimal bone. The upper end articulates with the nasal notch of the frontal bone between the nasal and the lacrimal bones.

Alveolar process. The alveolar process forms a thick arched border which together with the fellow of its opposite side forms the alveolar arch. It is excavated to form eight sockets, into which the roots of the eight teeth articulate. The teeth that articulate with the sockets (gomphosis) from before backwards, are the medial incisor, lateral incisor, canine, first premolar, second premolar, first molar, second molar and third molar. The sockets for the incisors, canine and the second premolar are single sockets and that for the canine is deepest. The sockets for the molar teeth are wider and each is divided into three smaller sockets by two small septa. The socket for the first premolar may be subdivided into two sockets by a septum. The lateral surface opposite to the three molar teeth gives origin to buccinator muscle.

Zygomatic process. It is a short process situated at the junction of the orbital, anterior and posterior surfaces. By its rough articular surface it articulates with the maxillary process of the zygomatic bone. From its inferior aspect a smooth ridge runs downwards to the root of the second molar tooth which marks the line of demarcation between the anterior and posterior surfaces. Sometimes its inferior aspect gives origin to some fibres of the masseter muscle.

Palatine process. The palatine process of the maxilla forms an arched plate of bone that projects medially from the upper part of the medial aspect of the anterior three-fourths of the alveolar process. The palatine process of the maxilla together with the fellow of its opposite side forms the anterior three-fourths of the hard palate. Each consists of superior and inferior surfaces, lateral, medial and posterior borders. The superior surface is gently concave and forms the part of the floor of the corresponding nasal cavity. The inferior surface is rough and uneven and presents irregular pits for the lodgment of palatine glands. At the junction of its lateral border with the body posteriorly it presents a groove for greater palatine vessels and nerves. Opposite the incisor teeth it presents a small depression which together with the fellow of its opposite side forms the *incisive fossa,* at the bottom of which there is a canal on each side of the medial plane, the *incisive canal*. The incisive canal opens above into the corresponding nasal cavity and transmits the long sphenopalatine nerve to the hard palate and the greater palatine vessels to the nasal cavity. Some times a small suture may extend lateralwards from the margin of the incisive fossa and intervenes between the lateral incisor and the canine tooth and separates this portion of the bone together with the two incisor teeth from the rest of the bone and when this happens this portion of the bone is known as *os incisivum* which normally exists in some other vertebrate animals. The lateral margin of the palatine process fuses with the body. Its medial margin articulates with the fellow of its opposite side and forms a crest termed the nasal crest which articulates with the inferior margin of the vomer. The anterior portion of the nasal crest is raised to a considerable height and is known as the *incisor crest* into which the tip of the vomer fits. The anterior end of the incisor crest forms a projecting spine which with the fellow of its opposite side forms the *anterior nasal spine*. Its posterior border articulates with the anterior border of the horizontal plate of the palatine bone.

Maxillary air sinus. (See also paranasal sinuses). This is the largest of the paranasal sinuses and is contained within the body of the maxilla. Its base is formed by the nasal surface of the body; the apex corresponds to the zygomatic process; the roof is formed by the orbital surface and the floor is formed by the alveolar process. Its anterior and posterior walls correspond to the anterior and infratemporal (posterior) surfaces of the body. It measures 1½ inches in vertical diameter, one inch transversely and about 1¼ inches anteroposteriorly. It is lined by the mucous membrane derived from the nasal cavity.

Communication. It communicates with the middle meatus of the nose.

Ossification. Each of the maxillae develops in membrane and ossifies from two primary centres, one for the maxilla proper and one for the premaxilla, which appear during late sixth week of intrauterine life.

The centre for the maxilla proper appears first in that portion of the bone which lies above the canine tooth germ and then spreads to form the main mass of the bone together with its processes except that portion which bears the incisor teeth (os incisivum or premaxilla). The centre for the premaxilla appears above the incisor tooth germ and forms that portion of the bone which bears the incisor teeth. The premaxilla and the maxilla proper fuse together during the third month of intrauterine life.

During the fourth month of intrauterine life the maxillary air sinus begins to appear as shallow depression on the inner side of the bone and gradually increases in size until at puberty it assumes its normal size.

During the earlier part of development the alveolar border does not present the

characteristic feature of the border but during the process of development an elongated furrow, the *dental groove*, appears on this border. The walls of the dental groove grow downwards so as to convert the dental groove into a tunnel and the inner wall of the tunnel being called the *lingual plate* whereas the outer one, the *labial plate*. Later on, septa appear across the tunnel to divide it into five sockets for the five temporary or milk teeth. The socket for the canine tooth is the first to appear amongst them.

THE PALATINE BONE

The palatine bone lies on each side in between the pterygoid process of the sphenoid behind and the maxilla in front. Each palatine bone consists of a vertical part and a horizontal part and three processes, orbital, sphenoidal and pyramidal processes. The vertical plate ascends upwards with the orbital process in front and the small sphenoidal process behind. The horizontal part projects medially from the lower border of the vertical part. The tubercle or the pyramidal process projects backwards, downwards and laterally from the junction of the horizontal and the vertical parts.

Side determination. Hold the bone in such a way that the vertical or perpendicular plate holding the orbital process in front and the sphenoidal process behind projects upwards, the pyramidal process looks backwards, downwards and laterally and the latter will determine the side to which the bone belongs or the horizontal plate will determine the opposite side of the bone.

Vertical or perpendicular plate. The perpendicular plate of the palatine bone consists of medial and lateral surfaces and anterior, posterior, superior and inferior borders.

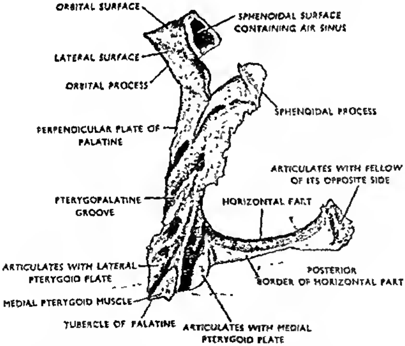


Fig. 414. The left palatine bone. Posterior view.

The *medial surface* presents below a depressed area which is continuous with the upper surface of the horizontal part and forms part of the lateral wall of the inferior meatus of the nose. Above this area there is a horizontal ridge known as the *conchal crest* which articulates with the posterior part of the superior border of

the inferior nasal concha. Above the conchal crest there is another shallow area which forms part of the lateral wall of the middle meatus of the nose. Above this area a small horizontal ridge, known as the *ethmoidal crest*, articulates with the middle nasal concha. A narrow groove above the ethmoidal crest forms a part of the superior meatus of the nose.

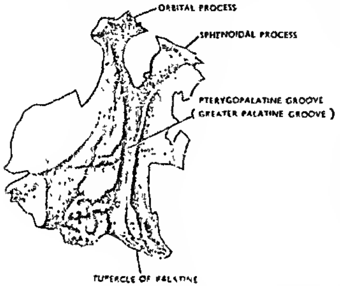


Fig 415 The left palatine bone Lateral aspect.

The *maxillary* or the *lateral surface* of the palatine bone is rough for the greater part of its extent and articulates with the nasal surface of the maxilla. A narrow smooth area at its postero-superior part forms part of the medial wall of the pterygopalatine fossa. The rough area close to its posterior part presents a vertical groove, the *greater palatine groove*, which is converted into greater palatine canal by articulation with the maxilla and transmits the greater palatine vessels and nerves.

The *anterior border* is irregular and opposite to the conchal crest it projects forwards as a process known as the *maxillary process* which covers the maxillary air sinus and articulates with the maxillary process of the inferior nasal concha. The *posterior border* articulates with the anterior border of the medial pterygoid plate of the sphenoid. The *superior border* surmounts the orbital process in front and the sphenoidal process behind and in between these two processes it forms a notch, the *sphenopalatine notch*, which is converted into sphenopalatine foramen by the undersurface of the body of the sphenoid in the articulated skull and transmits the sphenopalatine vessels and nerves from the pterygopalatine fossa to the upper part of the superior meatus of the nose. The *inferior border* fuses with the horizontal part.

Orbital process. The orbital process projects upwards and laterally from the upper and anterior part of the perpendicular plate and contains an air cell with broken margins. It consists of *three articular* and *two non-articular surfaces*. The articular surfaces are *anterior* or *maxillary*, *posterior* or *sphenoidal* and *medial* or *ethmoidal*. The non-articular surfaces are *superior* or *orbital* and *lateral*.

The *anterior* or *maxillary surface* looks downwards, forwards and laterally and articulates with the maxilla. The posterior or *sphenoidal surface* contains an air cell, the margins of which articulate with the sphenoidal concha. The *medial* or *ethmoidal* surface is directed upwards and medially and articulates with the labyrinth of the ethmoid. The *orbital* or *superior surface* is smooth and forms part of the floor of the orbit. It is continuous with the lateral surface by a smooth rounded border which forms a part of the lower margin of the inferior orbital fissure. The *lateral surface* is directed laterally and slightly backwards and presents a shallow groove in its lower part which lodges the maxillary nerve.

Sphenoidal process. The sphenoidal process consists of a thin lamina of bone which projects upwards and medially and lies at a lower level than the orbital process. It consists of *superior, infero-medial* and *lateral surfaces* and *anterior, posterior* and *medial borders*.

The *superior surface* forms a narrow depressed surface which articulates with the undersurface of the sphenoidal concha and forms the floor of the palatino-vaginal

canal which transmits the pharyngeal nerve from the pterygopalatine ganglion and the pharyngeal artery from the (internal) maxillary artery. The *infero-medial surface* is concave and is directed downwards and medially and forms part of the roof and

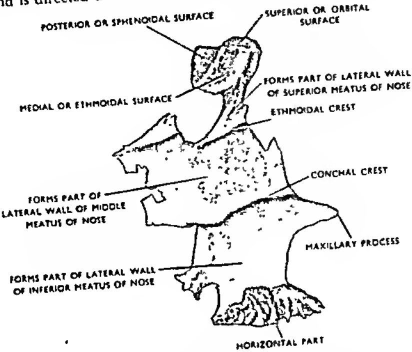


Fig. 416 The right palatine bone Medial aspect.

lateral wall of the nasal cavity. The *lateral surface* is divided into anterior and posterior parts by an indistinct vertical ridge. The posterior part articulates with the medial pterygoid plate of the sphenoid and the anterior part which is smooth, forms part of the medial wall of the pterygopalatine fossa.

The *anterior border* forms the posterior boundary of the sphenopalatine foramen. Its *posterior border* articulates with the vaginal process of the medial pterygoid plate. Its *medial margin* articulates with the ala of the vomer.

Horizontal part. The horizontal part projects medially from the lower margin of the perpendicular part and consists of superior and inferior surfaces and anterior, posterior, lateral and medial borders.

The *superior surface* is smooth and forms part of the floor of the inferior meatus of the nose. Its *inferior surface* is rough and marked by irregular pits for the palatal glands. At a short distance from its posterior border this surface presents a prominent ridge known as the *palatal crest* which together with the posterior border receives insertion of the expanded tendon of the tensor palati muscle and gives attachment to palatal aponeurosis. It forms the posterior one-fourth of the hard palate.

The *anterior border* is articular and articulates with the posterior border of the palatine process of the maxilla. Its *posterior border* is thin, concave and non-articular and gives attachment to the tensor palati muscle. Its medial end curves backwards into a process which together with the fellow of its opposite side forms the *posterior nasal spine* and gives attachment to musculus uvulae. Its *lateral margin* fuses with the inferior margin of the perpendicular part. Its *medial border* articulates with the fellow of its opposite side and forms a crest into which the posterior part of the inferior border of the vomer fits..

Tubercle or the pyramidal process. The tubercle or the pyramidal process projects downwards, backwards and laterally from the junction of the horizontal and perpendicular parts. It consists of posterior, lateral and inferior surfaces.

The *posterior surface* is limited on either side by an articular furrow which articulates with the margins of the pterygoid fissure and encloses a smooth traingular area which forms part of the pterygoid fossa and gives origin to some of the fibres of the medial pterygoid muscle. The *lateral surface* articulates with the maxillary tuberosity. Its *inferior surface* is smooth and non-articular and presents one or two foramina, the *lesser palatine foramina*, for the transmission of the lesser palatine vessels and nerves

Ossification. Each palatine bone develops in membrane and ossifies from one primary centre which appears during the eighth week of intrauterine life at the perpendicular plate. From this point the process of ossification extends upwards into the perpendicular plate and then spreads into the orbital and sphenoidal processes, downwards into the tubercle of palatine bone and medialwards into the horizontal plate.

THE ZYGOMATIC BONE

The zygomatic bones are two in number and each occupies the infero-lateral aspect of the orbital opening and forms the prominence of the cheek. Each zygomatic bone consists of three surfaces, five borders and two processes. The surfaces are malar (lateral), medial or temporal and orbital. The orbital surface forms a shelf-like projection which looks medially and backwards from the antero-superior aspect of the bone. The malar (lateral) surface is convex whereas the temporal surface is concave. Its borders are antero-superior, antero-inferior, postero-superior, posteroinferior and posteromedial. The posterosuperior border resembles the italic letter '*f*' and is non-articular. The anterosuperior border is rounded and forms part of the infraorbital margin. Its processes are frontal and temporal. The frontal process projects upwards between the anterosuperior and posterosuperior borders.

Side determination. Hold the bone in such a way that the non-articular posterosuperior border resembling italic letter '*f*' looks upwards and backwards, the frontal process looks upwards and the convex malar (lateral) surface will determine the side to which it belongs.

The *malar (lateral) surface* is convex and looks laterally and forwards and presents near the orbital margin the openings of the *zygomaticofacial foramen* which transmits the zygomaticofacial vessels and nerves. Below this opening it presents a low rounded elevation which gives origin to zygomaticus minor muscle and the area posterior to it gives origin to zygomaticus major muscle. Close to the postero-inferior margin this surface gives origin to some of the fibres of the masseter muscle. The *medial or temporal surface* is concave and forms part of the infratemporal fossa and presents the opening of the *zygomaticotemporal foramen* which transmits the zygomaticotemporal vessels and nerves. Anteriorly this surface presents a rough articular area which articulates with the maxilla. The *orbital surface* forms an expanded plate of bone which projects medially and backwards from the orbital margin (Anterosuperior border). It is smooth and gently concave and forms part of the floor and the lateral wall of the orbit. Above and posteriorly it is continuous with the frontal process.

The *anterosuperior border* is rounded and smooth and forms part of the infraorbital margin. The *anteroinferior margin* is rough and articular and articulates with the maxilla. Close to the orbital margin this border gives origin to some fibres of the levator labii superioris. The *postero-superior border* is non-articular and resembles the italic letter '*f*' and above it is continuous with the frontal process and below it is continuous with the temporal process. A little below the fronto-zygomatic suture this border presents a prominence known as the *marginal tubercle* which forms a bony landmark below the fronto-zygomatic suture. It gives attachment to the temporal fascia. The *postero-inferior border* is also non-articular and it is thick and marked by muscular impression for the origin of the masseter muscle. The *postero-medial border* is articular and at first slopes from above downwards and laterally, then downwards and forwards, and between these two slopes it usually presents a non-articular area

which forms the lateral boundary of the inferior orbital fissure. The upper slope articulates with the greater wing of the sphenoid (lateral margin of the orbital surface) and the lower slope articulates with the maxilla.

The FRONTAL PROCESS projects upwards and forms a three-sided bony process. *Its anterior border* is continuous with the orbital margin, its *posterior border* is continuous with the postero-superior border and its *medial margin* is continuous with the posteromedial border. Above it forms a serrated edge which articulates with the zygomatic process of the frontal bone. Its medial margin articulates with the greater wing of the sphenoid. Its narrow lateral surface merges into the lateral surface of the body and its posterior surface is continuous with the medial surface. Its anterior surface is continuous with the orbital surface. On this surface close to the orbital margin about half an inch below the fronto-zygomatic suture it presents a small tubercle (*tubercle* of *Whitnol*) which gives attachment to the check ligament of the rectus lateralis, part of the aponeurosis of the levator palpebrae superioris, suspensory ligament of the eye ball and the lateral palpebral ligament.

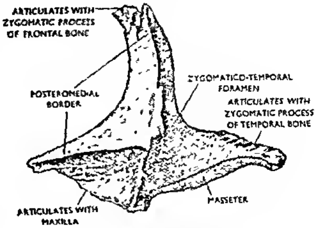


Fig. 417. The right zygomatic bone; internal aspect with attachments.

Fig. 418. The right zygomatic bone; external aspect with muscular attachments.

The TEMPORAL PROCESS projects backwards from the posteroinferior part of the bone and presents a serrated edge which articulates with the zygomatic process of the temporal bone and completes the zygomatic arch. Its lower border gives origin to some fibres of the masseter and its upper border gives attachment to the temporal fascia.

Ossification. Each of the zygomatic bones develops in membrane and usually ossifies from one centre which appears during the eighth week of intrauterine life.

Very rarely the bone ossifies from more than one centre in which different centres fuse together during the end of the fourth month of intrauterine. The bone may rarely be seen to be split into two portions, upper and lower, thus justifying the presence of different centres of ossification.

THE HYOID BONE

The hyoid bone forms an 'U'-shaped arch the convexity of which is directed upwards and forwards whereas its concavity looks downwards and backwards. It forms a broader central part known as the *body* and from the lateral *ends of the body* the narrower prolongation of the bone is known as the *greater cornu*. From the junc-

tion of the greater cornu and the body a small conical bony process projects upwards known as the *lesser cornu.*

The BODY of the hyoid bone forms a flattened arch of bone the convexity of which looks upwards and forwards. It consists of anterior and posterior surfaces and superior and inferior borders and two lateral ends. The *anterior surface* is convex and presents opposite the median plane a vertical ridge which is well marked above and less so below. This represents the line of fusion betwen the two halves of the body. A transverse arched ridge, the convexity of which is directed downwards, divides the anterior surface into upper and lower areas. On each side of the median plane the anterior surface of the body is rough for muscular and ligamentous attachments. *Geniohyoid* muscle is inserted over a rough impression having a concavity laterally and extends both above and below the transverse ridge. Lateral to the geniohyoid and encroaching into the folds of its insertion is the *hyoglossus muscle* which extends into the greater cornu. Below the geniohyoid and hyoglossus the *mylohyoid* makes its insertion. Below the mylohyoid, *sternohyoid* and *omohyoid* (superior belly) make their insertion, of which sternohyoid is medial and the omohyoid is lateral. Lateral to the mylohyoid the most medial fibres of the *thyrohyoid* is inserted. Above the geniohyoid the anterior surface gives origin to some fibres of *genioglossus muscle*. The *posterior surface* is in relation to a bursa. The superior border gives attachment to the *hyothyroid membrane* and to the *hyoepiglottic ligament* and to some fibres of genioglossus muscle. The fibres of insertion of the omohyoid, sternohyoid, and thyrohyoid encroach on to the inferior border.

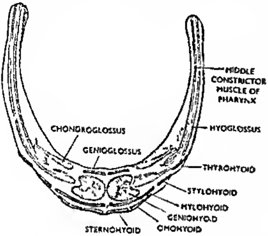


Fig. 419. The hyoid bone with attachments Seen from the front.

The anterior surface of the *greater cornu* gives origin to *hyoglossus muscle* which extends from the body, and to the *middle constrictor muscle* of the *pharynx* which extends from the lesser cornu. The middle constrictor muscle lies above the hyoglossus. Below the hyoglossus the anterior surface of the greater cornu gives insertion to *stylohoyid* and attachment to the fibrous loop that anchors the central tendon of the digastric muscle to the hyoid bone. Its posterior aspect gives attachment to the *hyothyroid membrane.*

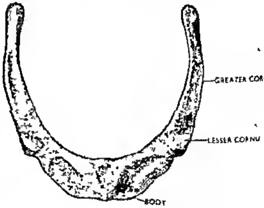


Fig. 420. The hyoid bone. Seen from the front

The *lesser cornu* projects forwards from the junction of the greater cornu and the body. It gives attachment to the *stylohyoid ligament* which suspends the byoid bone from the styloid process of the temporal bone. It gives origin to *middle constrictor muscle of the pharynx* and to the *chondrolgossus muscle.*

Ossification. The hyoid bone develops in cartilage and is derived from the cartilaginuous bars of the second and the third pharyngeal arches. The ventral ends of the cartilages of the second and the third arches are fused together to form the body

of the hyoid bone (basihyal), the remaining unfused portion of the third arch cartilage forms the greater cornua (thyrohyal); while the lesser cornua are formed from the cartilage of the second arch (ceratohyal).

The bone is ossified from six centres, two for the body, one for each of the greater and lesser cornua. Just before birth the centres for the body and the greater cornua appear while that for the lesser cornua appear during the first or the second year or even later until puberty.

THE MANDIBLE

The mandible is the largest and strongest bone in the face and presents a horse-shoe-shaped body from the posterior ends of which the two rami of the mandible project upwards.

The body of the mandible forms a flattened arch of bone the convexity of which is directed forwards and resembles a horse-shoe in appearance. It consists of external and internal surfaces and superior and inferior borders.

The *external surface* of the body is convex in outline and opposite the upper part of the median plane it presents a faint ridge which marks the line of fusion between the two halves of the body and ends below on the summit of a small eminence known as the *mental protuberance* (prominence of the chin). The mental protuberance is roughly triangular in form the apex of which is directed upwards and the base downwards. Opposite the lateral angles of the base of the mental protuberance there is a small tubercle known as the *mental tubercle*. An oblique line known as the *oblique ridge* ascends upwards and backwards from the mental tubercle across the body and is continuous behind with the anterior border of the ramus. Its posterior part is well defined whereas its anterior part is indistinct. The anterior end of the oblique line gives origin to depressor labii inferioris in front and to the depressor anguli oris behind. On either side of the median ridge it presents a small depression known as the *mental fossa* which gives origin to mentalis muscle and to a part of the orbicularis oris. Immediately below the interval between the first and the second premolars (between the fourth and the fifth teeth from the median plane) there is the opening of the *mental foramen* which leads into the mandibular canal and transmits the mental vessels and nerves. The portions of the external surface of the body adjoining the roots of the teeth are covered by the muco-periosteum and opposite the three molar teeth it gives origin to the *buccinator muscle*.

The *internal surface* of the body of the mandible is concave and is traversed from above downwards by an oblique ridge known as the *mylohyoid line*. The mylohyoid line begins from opposite the level of the last molar tooth at a distance of about ½ inch from the same and descending downwards and forwards ends in the lower part of the symphysis menti below an irregular eminence, known as the *genial tubercles*. The mylohyoid line gives origin to *mylohyoid muscle* throughout its whole length and *from its posterior end it gives origin to a slip of the superior constrictor muscle of the pharynx* which encroaches between it and the last molar tooth. Behind the last molar tooth the portion of the bone gives attachment to *pterygomandibular ligament*. Below the mylohyoid line is an oblique groove known as the *mylohyoid groove* which lodges the mylohyoid vessels and nerves. The mylohyoid line subdivides the internal surface into two triangular areas. The apex of the lower triangular area is directed forwards whereas the apex of the upper triangular area is directed backwards. The base of the lower triangular area is hollowed out and is known as the *submandibular fossa* for the lodgement of the submandibular salivary gland and some of the submandibular lymph glands. The base of the upper triangular area is also hollowed out and is known as the *sublingual fossa* for the lodgement of the sublingual salivary gland. The margin of the bone close to the roots of the teeth is covered by mucoperiosteum. The genial tubercles which are placed above the anterior ends of the mylohyoid lines in the median plane may be divisible into four tubercles—two upper and two lower. The upper genial tubercles give origin to the *genioglossus muscle* whereas the lower genial tubercles give origin to *geniohyoid muscle*. Below the anterior end of the mylo-

hyoid line and on either side of the median plane is a shallow depression known as the *digastric fossa* which gives origin to the anterior belly of the digastric muscle.

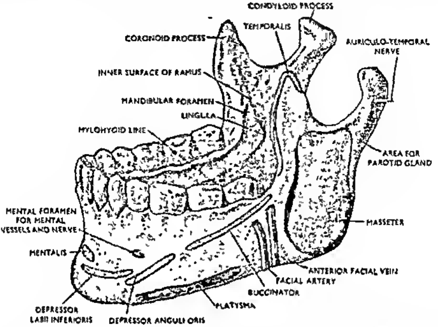


Fig 421. The mandible with attachments and relations. Seen from the left side.

The superior border of each half of the mandible (body) is excavated into eight sockets into which from before backwards the following teeth articulate.

(1) Medial incisor.	(5) Second premolar.
(2) Lateral incisor.	(6) First molar.
(3) Canine.	(7) Second molar.
(4) First premolar.	(8) Third molar.

The sockets of the molar teeth are divided into two compartments by a septum.

The lower border of the body of the mandible is rounded and constitutes the base of the mandible. Platysma is inserted into the lower border and anteriorly it extends over the external surface of the mandible to reach the lower part of the face where it forms the risorius muscle.

The ramus of the mandible projects upwards from the posterior end of the body and forms a square flattened bone which is surmounted above and in front by the *coronoid process*, and above and behind by the *condyloid process*. Each ramus consists of external and internal surfaces and anterior, posterior, superior and inferior borders and coronoid and condyloid processes.

The *external surface* of the ramus is rough throughout its entire extent except its upper and posterior part where it forms a smooth area. The rough area gives insertion to the masseter muscle. At the lower part of the rough area there are a few short vertical ridges which give attachment to the intramuscular tendon of the same muscle. The upper and posterior smooth area is covered by the parotid gland.

The *internal surface* of the ramus presents a foramen at its middle point known as the *mandibular foramen* which leads into the mandibular canal and transmits the *inferior dental vessels and nerves*. The medial margin of the mandibular foramen forms a sharp bony process known as the *lingula* which gives attachment to the *sphenomandibular ligament*. Behind the mandibular foramen and the lingula is a vertical groove which marks the commencement of the mylohyoid groove and transmits the *mylohyoid vessels and nerves*. The internal surface of the ramus below and behind the

mylohyoid groove is marked by a rough impression which gives insertion to the *medial pterygoid muscle*.

The *anterior border* of the ramus is sharp and prominent and is continuous below with the oblique line of the body and above with the anterior border of the cornoid process. It gives insertion to some fibres of the *temporalis muscle*. The *posterior border* is rounded and presents a slight concavity opposite its mid-point. It is in relation to the parotid gland. The posterior border is continuous above with the posterior border of the condyle. The *superior border* forms a concave notch known as the *mandibular notch* and joins the coronoid process in front with the condyloid process behind. The mandibular notch transmits the masseteric vessels and nerves. The *inferior border* is very short and joins with the posterior border at an angle known as the *angle of the mandible* and gives attachment to the *stylomandibular ligament* which intervenes between the parotid and the submandibular glands. Anteriorly the inferior border of the ramus is continuous with the base of the mandible.

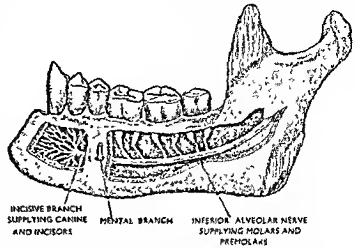


Fig. 422. The mandible with opened up mandibular *canal from the exterior to show the inferior alveolar nerve* and its branches.

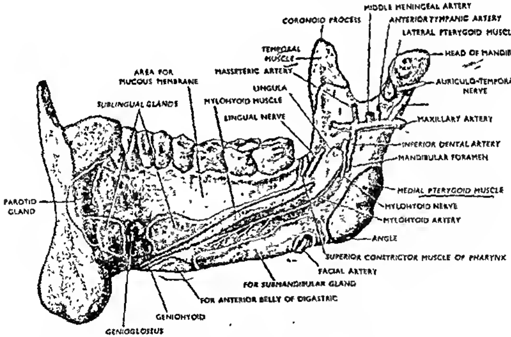


Fig. 423. The mandible. Internal aspect with attachments and relations.

The CORONOID PROCESS is a triangular piece of bone that projects upwards from the anterior aspect of the upper portion of the ramus. Its anterior border is continuous with the anterior border of the ramus. Its posterior border forms the anterior border of the mandibular notch. The whole of its medial surface, a part of the lateral

surface close to its apex and its anterior margin receive insertion of the *temporalis muscle*.

The CONDYLOID PROCESS ascends upwards from the upper and posterior part of the ramus. Its upper end forms an expanded, thick prominence and is known as the *head* of the mandible which is lined by articular cartilage and articulates with the articular fossa of the temporal bone by the intervention of a fibro-cartilaginous disc and forms the mandibular joint. It is broader transversely than antero-posteriorly and presents a round tubercle on its lateral aspect which together with the adjoining lateral and posterior aspects of the neck gives attachment to the *tempro-mandibular ligament*. Below the expanded head the narrow portion of the bone constitutes the *neck* of the mandible. Immediately below the anterior part of the head there is a depressed area which gives insertion to the *lateral pterygoid muscle*.

The *mandibular canal* begins in the mandibular foramen and at first runs vertically downwards and then runs horizontally forwards to the interval between the first and the second premolars where it ends by dividing into *mental* and *incisive canals*. The mandibular canal transmits the inferior dental vessels and nerves which become mental and incisive vessels and nerves at the point of bifurcation of the canal.

Ossification. The mandible develops partly in membrane and partly in cartilage. The most of its parts are developed from the fibrous membrane covering the outer surface of the Meckel's cartilage (cartilage of the first pharyngeal arch) and a small part by ossification of the anterior end of the Meckel's cartilage, and from the symphyseal, coronoid and condyloid cartilages. At birth the bone consists of two halves being united together anteriorly at the symphysis menti by fibrous tissue. Each half of the bone ossifies from one centre which appears during the sixth week of foetal life in the fibrous membrane covering the surface of the Meckel's cartilage in the region of the future mental foramen and then the process of ossification spreads to the adjoining portion. The mandible forms the second bone in order of time to show signs of ossification (the clavicle being the first). The different portion of the bone ossifies as follows:

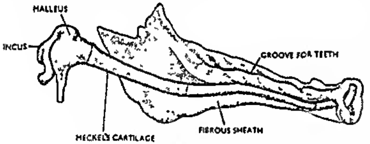


Fig. 424 The development of the mandible from the Meckel's cartilage.

The body. The incisive portion of the body together with the symphysis menti develops in cartilage and ossifies from the anterior end of the Meckel's cartilage and from the symphyseal cartilage which are invaded by an extension of ossification from the primary centre in the remaining portion of the body.

The remaining portion of the body develops in membrane which covers the outer surface of Meckel's cartilage and ossification first starts in this portion in the region of the future mental foramen.

The ramus. The portion of the ramus as far as the mandibular foramen develops in membrane in association with the body and the rest of the ramus above the mandibular foramen develops in cartilage from the coronoid and condyloid cartilages.

The Coronoid process. It develops in cartilage from the coronoid cartilage.

The Condyloid process. It develops in cartilage from the condyloid cartilage.

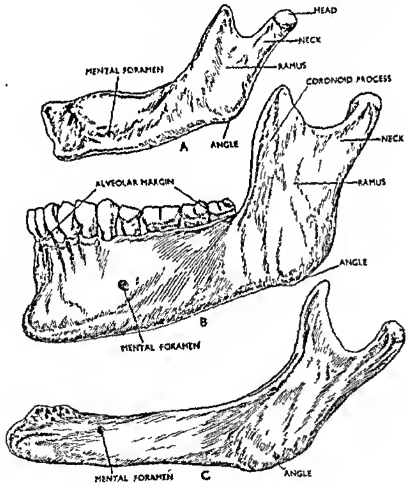
The fate of the Meckel's cartilage or the cartilage of the first pharyngeal or visceral arch. The Meckel's cartilage forms the skeletal element of the first pharyngeal arch and is developed in situ by mesodermal condensation. It forms a bar of cartilage which is connected dorsally, with the periotic cartilaginous capsule of the chondrocranium

at the base of the developing cranium and then descending downwards and forwards its ventral end meets the fellow of its opposite side in the median plane. Throughout its course it is surrounded by a fibrous capsule.

From its extreme dorsal end the two of the three auditory ossicles namely, malleus and incus are formed; the portion extending from the base of the skull to the mandibular foramen atrophies while its fibrous investment in this situation persists to form the sphenomandibular ligament; the portion extending from the mandibular foramen to the mental foramen also atrophies and its fibrous capsule in this situation forms the greater portion of the mandible; its extreme vental portion persists and together with the symphyseal cartilage it forms the incisive portion of the body of the mandible.

AGE CHANGES OF THE MANDIBLE

The mandible is a bone which shows remarkable changes with age because of the obvious reasons that it is associated with teeth which appear in two crops and



A Mandible at birth.
B Mandible in the adult.
C Mandible in extreme old age.
Fig. 425. The age changes in mandible.

disappear again in old age. The permanent teeth, which replace the temporary ones, are larger and more in number by 10 and therefore to accomodate the excess teeth the teeth bearing area must increase and at the same time to accomodate the larger teeth more space is required to keep the occlusional surfaces of the teeth

in perfect order; this is effected by growth in height of the ramus of the mandible. With the loss of the teeth the condition again changes. The changes that occur are brought about by the process of moulding in which, depending on the necessity, there is harmonious deposition of new bone and resorption of the old one where required. The following are the changes of the mandible with age:

The mandible at birth. It is small in all respects, there are no teeth and the body of the bone forms a mear shell containing teeth sockets which are imcompletely partitioned from one another. The bone remains in two halves united together by fibrous tissue opposite median plane forming the *symphysis menti.* The coronoid process is larger and lies at a higher level than the condyloid process which roughly occupies the plane of the upper border of the body of the mandible. The mandibular canal is nearest to the lower border and the mental foramen occupies its position opposite the first deciduous molar tooth. The angle of the mandibe is obtuse.

The mandible just before the eruption of the first permanent tooth. The mandible grows in length particularly behind the mental foramen; the depth of the body also increases and the mandibular canal lies a little above the mylohyoid line and the mental foramen roughly occupies the adult position. The bone is endowed with 10 temporary teeth. The ramus grows in height and coronoid and condyloid processes are on the same level.

The mandible in the adult. The bone is now fully developed and contains 16 teeth. The mental foramen occupies its position mid-way between the upper and the lower borders opposite the interval between first and second premolars. The mandibular canal runs parallel with the mylohyoid line. The condyloid process is placed at a higher level than the coronoid process. The angle of the mandibe measures roughly a right angle.

The mandible in old age. It becomes edentulous, the alveolar process is absorbed and the alveolar border is reduced to an *alveolar ridge*. The mental foramen and the mandibular canal are very close to the upper border. The ramus is oblique in direction and the "angle" measures about 140°. The condyloid process is bent backwards.

SKULL VIEWED AS A WHOLE

The skull when viewed as a whole is irregularly ovoid in shape. Its top is convex in general outline being broader behind than in front. The coronal suture in front and the lambdoid suture behind cross transversely across the top of the skull in front and behind respectively and are joined together by an anteroposterior suture, the sagittal suture opposite the median plane and form a H-shaped suture which demarcates roughly four bones namely two parietals, one on either side, the frontal bone in front and the occipital behind. The rest of the skull is most irregular. For purposes of description and as viewed from different aspects the skull may be divided into different regions as norma verticalis, norma basalis, norma frontalis, norma occipitalis and norma lateralis.

NORMA VERTICALIS

The norma verticalis or the top of the cranium is ovoid in general outline, convex in all directions and is broader behind than in front. It is formed by four bones, two parietals, one on each side, the frontal, in front and the occipital behind. The *sagittal suture* opposite the median plane is formed by articulation of the two parietal bones which in front articulate with the frontal bone at a transverse suture, the *coronal suture*. In a fully developed skull the sagittal suture meets the coronal suture almost at right angle and the point of meeting between the two is known as *bregma*. In the new born as the angles of the parietals and the adjoining portion of the frontal bone remain membranous and unossified the coronal and the sagittal sutures meet

each other by a diamond-shaped membrane known as the *anterior fontanelle.* Posteriorly the two parietal bones articulate with the occipital bone and the suture between them is known as the *lambdoid suture.* In the grown-ups the point of union between the sagittal suture and the lambdoid suture in the median plane is known as *lambda.* In the new born this area is occupied by a triangular membranous area known as the *posterior fontanelle.*

Roughly mid-way between the coronal and the lambdoid suture, on either side of the sagittal suture over the parietal bone the most prominent lateral bulging is known as the *parietal eminence.* The widest part of the norma verticalis and also the widest part of the skull as a whole corresponds to a line joining the two parietal eminences. Both in front of and behind the parietal eminences the skull narrows in diameter. Posteriorly the skull slopes abruptly medialwards and backwards to meet an ovoid bulging, the *external occipital protuberance,* so as to resemble the arc of a parabola. Anteriorly from the level of the parietal eminences the skull slopes medially and forwards to a broad shallow transverse constriction situated just behind the coronal suture and then slightly widens and again slopes to the frontal eminences.

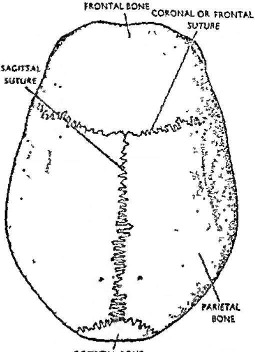


Fig. 426. The top view of the skull.

About 3 cm. in front of the lambda either in the sagittal suture or on either side of it on the parietal bone, is the *parietal foramen* which in the recent state transmits an emissary vein and a branch from the occipital artery.

The vault of the skull or the norma verticalis in the recent state is covered by scalp which consists of 5 layers and from without inwards they are (1) skin, (2) dense subcutaneous tissue, (3) epicranial aponeurosis, (4) layer of loose areolar tissue and (5) the pericranium.

The pericranium forms the periosteum of the bones and is easily separable from the subjacent bone except opposite the sutures where it is firmly adherent. The loose areolar layer occupies an wide area mostly limited by the attachments of the occipito-frontalis muscle and the temporal fascia and it is due to the presence of this layer over the fixed pericranium that the rest of the scalp moves so freely. The skin, dense subcutaneous tissue and the epicranial aponeurosis, all are condensed to one layer.

NORMA BASALIS

Norma basalis or roughly the inferior aspect of the skull is most irregular and as it forms the basis on which the rest of the skull stands it is called "Norma Basalis". The mandible is usually excluded from its description and excluding it the boundary of the base of the skull is as follows:

Boundary:

Anteriorly. By incisor teeth of maxillae.
Posteriorly. By the superior nuchal lines of the occipital bone.
Laterally. By alveolar arch containing the remaining teeth (canine to last molar), the zygomatic arch with its posterior root, by the mastoid process and by a line joining the latter with the lateral end of the superior nuchal line.

For the purposes of description the external aspect of the base of the skull is divided into three portions, the *anterior portion* or the *hard palate*, the *middle portion* and the *posterior portion*. The portion behind the hard palate and lying on a level higher than it, is a wide area which is arbitrarily divided into middle and posterior portions by passing a transverse line through the anterior margin of the foramen magnum.

Anterior part of the norma basalis or the hard palate. The anterior part of the norma basalis occupies the gap within the horse-shoe-shaped arch formed by the alveolar processes of the maxillae and constitutes the *hard palate*. About $\frac{3}{4}$ of the hard palate is formed by the palatine processes of the maxillae and the remaining $\frac{1}{4}$ by the horizontal parts of the two palatine bones. A cruciate suture, the vertical limb of which is formed by inter-maxillary and inter-palatine sutures and the horizontal limb by the palato-maxillary suture, separates the different bony elements forming the hard palate.

It forms a dome-shaped arch, the summit of which rises much above the level of the teeth and the alveolar processes of the maxillae, and in the recent state forms the dome-shaped roof of the mouth cavity.

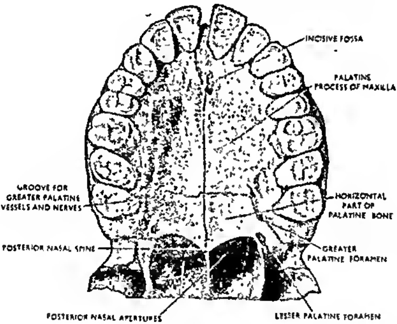


Fig. 427. The hard palate. Seen from below.

Anteriorly, opposite the median plane and behind the incisor teeth, is a deep depression known as the *incisive fossa*; on its lateral wall, on each side, is a foramen, the *lateral incisive foramen* which leads to a bony canal the *incisive canal*, which ends by opening into the floor of the nasal cavity. The lateral incisive foramen transmits the terminal branches of the greater palatine vessels and the long sphenopalatine nerve. In some skulls on the anterior and posterior walls of the incisive fossa there are two *median incisive foramina*, anterior and posterior. When present, the anterior median incissive foramen transmits the left sphenopalatine nerve while the right passes through the posterior median incisive foramen. At the postero-lateral angle of the hard palate is an opening, the *greater palatine foramen* which forms the lower opening of the greater palatine canal and transmits the greater palatine vessels and nerves. Running forwards from the greater palatine foramen is a groove which is deeper behind than in front and lodges the greater palatine vessels and nerves which pass towards the incisive fossa. The pyramidal process (tubercle) of the palatine bone projects backwards and laterally from the postero-lateral corner of

the hard palate. It is pierced by one or two small foramina, the *lesser palatine foramina* which transmit lesser palatine nerves. The surface of the vault of the hard palate is very rough and uneven. It is marked by irregular depressions for the lodgment of palatine glands and is pierced by numerous vascular foramina. Close in front of the posterior border on the horizontal part of the palatine bone there is a curved ridge, the *palatine crest* which gives insertion to the tendon of tensor palati muscle. The posterior border of the hard palate is free and concave and projects backwards opposite the median plane to form the *posterior nasal spine* which gives attachment to musculus uvulae. The free posterior border gives attachment to the palatine aponeurosis.

The middle part of the norma basalis

The middle part of the norma basalis occupies the interval between the posterior border of the hard palate and an imaginary line drawn transversely across the anterior margin of the foramen magnum. On either side it is limited by the zygomatic arch including its posterior root.

When viewed from before backwards in the median plane the posterior border of the nasal septum formed by the posterior border of the vomer is seen to stand out prominently which separates the two posterior nasal apertures. Behind the posterior border of the vomer is a broad piece of bone formed by the fusion of the body of the sphenoid and the basilar part of the occipital bone. Closely behind the posterior border of the vomer on this is a rounded elevation, the *pharyngeal tubercle* which gives attachment to the fibrous raphe from the pharynx. The portion of the bone in front of the pharyngeal tubercle forms the roof of the pharynx and is occupied by pharyngeal tonsils (Adenoid) in the recent state. On either side of the pharyngeal tubercle the longus capitis muscle is inserted. More posteriorly at the anterior end of occipital condyle the bone gives insertion to rectus capitis anterior.

On either side of the posterior border of the vomer, the superior border of the vomer spreads into two projecting alae, one on each side, which are closely applied to the under-surface of the body of the sphenoid and the lateral margin of each articulates with the vaginal process of the medial pterygoid plate of the sphenoid. The undersurface of the vaginal process presents a groove which is converted into a canal anteriorly by the superior surface of the sphenoidal process of the palatine bone and is known as the *palatinovaginal canal* which transmits the pharyngeal nerve from the sphenopalatine ganglion and the pharyngeal branch from the internal maxillary artery. Another canal known as the *vomerovaginal canal* occupies the upper surface of the vaginal process of the medial pterygoid lamina and the ala of the vomer. Anteriorly it communicates with palatino-vaginal canal.

On either side of the posterior nasal aperture and descending just behind the last molar tooth is the *pterygoid process* of the sphenoid bone. It consists of two laminae known as the *medial* and the *lateral pterygoid plates*. Anteriorly the two pterygoid plates are fused together except inferiorly where the V-shaped interval between them known as the *pterygoid fissure* is occupied by the tubercle of the palatine bone. Posteriorly the two plates diverge apart and enclose a fossa between them known as the *pterygoid fossa* which is occupied by the tensor palati and the medial pterygoid muscles in the recent state. Anteriorly the margins of the pterygoid fissure articulate with the tubercle of the palatine bone; above it the anterior margin of the *medial pterygoid* plate articulates with the posterior border of perpendicular plate of the palatine bone and together with it the medial pterygoid plate forms the lateral wall of the posterior part of the nasal cavity and is covered by the mucoperiosteum in the recent state. The posterior border of the medial pterygoid plate projects directly backwards and in its mid-point it presents a small sharp bony projection (processus tubarius). Just above this bony projection the posterior border gives attachment to the pharyngeal end of the pharyngo-tympanic tube. Superiorly this border bifurcates to enclose a shallow depressed area known as the *scaphoid fossa* which gives origin to tensor palati muscle. Inferiorly the posterior border projects more downwards than the rest of the bone and forms a curved bony process known as the *ptery-*

goid hamulus. The posterior aspect of the pterygoid hamulus gives origin to the highest fibres of the superior constrictor muscle of the pharynx and around its lateral margin the tendon of the tensor palati muscle glides. The tip of the pterygoid hamulus gives attachment to the pterygomandibular ligament. The posterior

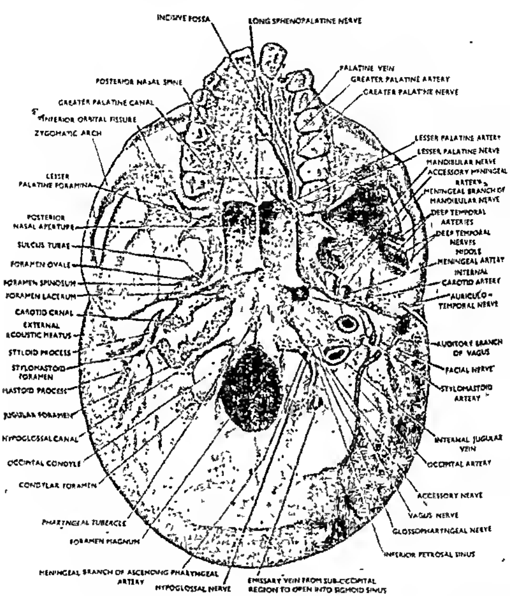


Fig. 428. The inferior aspect of the norma basalis with features and relations.

border of the medial pterygoid plate gives attachment to the pharyngo-basilar fascia and thus helps to form the lateral wall of the nasal part of the pharynx. At the upper end of the posterior border of the medial pterygoid plate is a tubercle which hides the posterior aperture of the *pterygoid canal* which transmits the pterygoid vessels and nerves. The medial surface of the medial pterygoid plate is covered by mucoperiosteum and forms the lateral boundary of the posterior nasal aperture. Its lateral surface forms the medial wall of the pterygoid fossa and is occupied by the tensor palati muscle.

The anterior margin of the lateral pterygoid plate remains free above the pterygoid fissure and forms the posterior margin of the *pterygo-maxillary fissure*. Its posterior margin is irregular and sometimes presents a bony projection known as the *pterygospinous process*, which gives attachment to pterygospinous ligament which is sometimes ossified. The medial surface of the lateral pterygoid plate forms the lateral wall of the pterygoid fossa and gives origin to the deep head of the medial pterygoid muscle. Its lateral surface is rough and is continuous with the infratemporal surface of the greater wing of the sphenoid. It forms a part of the infratemporal fossa and gives origin to the inferior head of the lateral pterygoid muscle. Inferiorly the lateral aspect of the lateral pterygoid plate is continuous with the lateral aspect of the tubercle of the palatine bone which intervenes, in this situation, between the lateral pterygoid plate and the tubercle of the maxilla and gives origin to the superficial head of the medial pterygoid muscle.

Lateral to the pterygoid process a part of the norma basalis is formed by the infratemporal surface of the greater wing of the sphenoid bone and forms the roof of the infratemporal fossa. More laterally is the suture between the greater wing of the sphenoid and the squamous part of the temporal bone and beyond this suture is the anterior root of the zygoma. The anterior margin of the anterior root of the zygoma is continuous with the infratemporal crest on the greater wing of the sphenoid which separates the temporal and infratemporal surfaces of the greater wing of the sphenoid. Between this anterior margin of the anterior root of the zygoma and the articular eminence is a triangular area which forms a part of the roof of the infratemporal fossa.

The infratemporal surface of the greater wing of the sphenoid in this situation gives origin to the upper head of the lateral pterygoid muscle which hides this area from view in the recent state. Lateral to the scaphoid fossa on the infratemporal surface of the greater wing of the sphenoid is a large oval aperture, the *foramen ovale* which transmits the mandibular nerve, the accessory meningeal artery and sometimes lesser superficial petrosal nerve. Lying lateral to the foramen ovale is the *foramen spinosum* which transmits the meningeal branch of mandibular nerve (nervus spinosus) and the middle meningeal vessels. The auriculotemporal branch of the mandibular nerve arises by two roots is this situation and as they pass lateralwards they enclose the middle meningeal vessels and soon unite beyond them to form the nerve, trunk. Postero-medially the greater wing of the sphenoid articulates with the petrous part of the temporal bone. Projecting downwards in the angle between the squamous and the petrous parts of the temporal bone is a bony process known as the *spine of the sphenoid*. It gives attachment to the sphenomandibular and pterygospinous ligaments and to some fibres of the tensor palati muscles. The groove on its medial aspect is in relation with the chorda tympani nerve while its lateral aspect is in relation with the trunk of the auriculotemporal nerve.

The posterior border of the greater wing of the sphenoid articulates with the petrous part of the temporal bone and the line of fusion between the two is marked by a shallow oblique groove known as the *sulcus tubae* and lodges the cartilaginous part of the auditory (pharyngotympanic) tube. Anteromedially the sulcus tubae is continuous with the scaphoid fossa and posterolaterally it opens into the canal for the bony part of the auditory (pharyngotympanic) tube. The cartilaginous part of the auditory (pharyngotympanic) tube is sandwitched between two muscles in this situation, the tensor palati muscle anterolaterally and the levator palati muscle posteromedially.

Behind the sulcus tubae and between the posterior border of the greater wing of the sphenoid and the basilar part of the occipital bone is the inferior aspect of the petrous part of the temporal bone. Anteriorly this aspect of the petrous part of the temporal bone is rough and uneven and close to the sulcus tubae near the apex of the petrous bone it gives origin to the levator palati muscle which runs obliquely forwards and medially along the posteromedial aspect of the cartilaginous part of the pharyngotympanic tube. Anteromedially the apex of the petrous part of the temporal bone is separated from the postero-lateral aspect of the body of the sphenoid by an irregular aperture known as the *foramen lacerum*. It is bounded in front by the pos-

terolateral aspect of the body of the sphenoid and the adjoining parts of the roots of the pterygoid process and the greater wing of the sphenoid, postero-laterally by the apex of the petrous part of the temporal bone and medially by the basilar part of the occipital bone. Postero-laterally the anterior end of the carotid canal opens into it whereas the posterior opening of the pterygoid canal opens into its anterior wall. In the recent state this is filled up by a plate of cartilage which represents the remnant of the primitive chondrocranium. An emissary vein which joins the cavernous sinus, some meningeal lymphatics and the meningeal branch of the ascending pharyngeal artery traverse this foramen through and through by piercing the cartilage whereas its anterior part lodges the internal carotid artery with its plexus of sympathetic nerves, the greater superficial petrosal nerve and the pterygoid vessels and nerves. The carotid plexus of sympathetic gives rise to the deep petrosal nerve in this situation which joins with the greater superficial petrosal nerve to form the nerve of the pterygoid canal (Pterygoid nerve).

Behind the rough anterior part of the inferior aspect of the petrous part of the temporal bone is a circular aperture which forms the *lower opening of the carotid canal* and transmits the internal carotid artery together with carotid plexus of nerves. Lateral to the external opening of the carotid canal the thin bony projection is the sheath of the styloid process and is formed by the tympanic part of the temporal bone. Lateral to the sphenoidal spine is the *squamo-tympanic fissure* which intervenes between the articular fossa of the squamous part of the temporal bone and its tympanic part. At the depth of the medial part of the squamo-tympanic fissure the downturned antero-lateral portion of the tegmen tympani forms a conspicuous projection and divides the squamo-tympanic fissure into *petrotympanic* and *petrosquamous fissures*. The petrotympanic fissure lodges the anterior ligament of the malleus and the anterior tympanic branch of maxillary artery. Its inner end forms the *anterior canaliculus for the chorda tympani nerve* and gives exit to the chorda tympani nerve.

The articular fossa formed by the squamous part of the temporal bone is deeply concave and articulates with the head of the mandible and forms the mandibular joint. Anteriorly it is bounded by a transverse eminence, the *articular eminence* into which the articular surface extends. It prevents forward displacement of the head of the mandible. The two roots of the zygomatic process meet laterally into a tubercle which gives attachment to the temporomandibular ligament.

Behind the squamo-tympanic fissure the thin plate of bone is formed by the tympanic part of the temporal bone. It forms part of the mandibular fossa and lodges a portion of the parotid gland to which the auriculotemporal nerve is intimately related. Posterolaterally it fuses with the mastoid part and the fissure between them is known as the *tympano-mastoid fissure* through which the auricular branch of the vagus nerve comes out. Its lower border is free and forms the sheath of the styloid process. Superiorly the tympanic part of the temporal bone is concave and forms the anterior wall, the floor and the lower part of the posterior wall of the bony external auditory meatus.

The posterior part of the norma basalis

The posterior part of the norma basalis commences from behind the imaginary line passing across the anterior margin of the foramen magnum. The *foramen magnum* forms the most conspicuous feature in this part and occupies the central position. It is roughly oval in shape being broader antero-posteriorly than from side to side. It communicates the vertebral canal to the posterior cranial fossa. Its largest transverse diameter occupies more anteriorly than posteriorly. Just in front of its midpoint it is overlapped on either side by the occipital condyles. The occipital condyles are placed obliquely so that their anterior ends are nearer the median plane than the posterior ends. The occipital condyles articulate with the superior articular facets on the lateral mass of the atlas. The anterior margin of the foramen magnum gives attachment to the anterior atlanto-occipital membrane which is fused posteriorly with the capsular ligament of the atlanto-occipital joint. The rough area on the medial aspect of the occipital condyle together with the adjoining margin of the

foramen magnum gives attachment to the alar ligament. The posterior margin of the foramen magnum gives attachment to the posterior altanto-occipital membrane. The alar ligament with its attachment on the dens (odontoid process) sub-divides the foramen magnum into an anterior smaller and a posterior larger compartment. The anterior smaller compartment transmits the odontoid process of the dens together with the apical ligament and the membrana tectoria. The larger posterior compartment transmits the lower end of the medulla oblongata together with its meninges and the tonsils of the cerebellum, and lying in the subarchnoid space, the spinal portion of the accessory nerve and the vertebral arteries with their plexus of sympathetic nerves ascend and the anterior and the posterior spinal arteries descend through the foramen. The anterior spinal artery descends in front of the brain stem in the median plane whereas the two posterior spinal arteries, one on each side, descend on the posterolateral aspect of the brain stem. The two tonsils of the cerebellum descend, one on either side of the medulla oblongata.

At the anterior end of the occipital condyle is the opening of the (*anterior condylar canal*) hypoglossal canal which transmits the hypoglossal nerve, the meningeal branch of the ascending pharyngeal artery and an emissary vein from the basilar plexus. Behind the occipital condyle is a depression the *condylar fossa* which is often pierced by a foramen for the transmission of an emissary vein.

Lateral to the occipital condyle is the *jugular process* which articulates with the jugular surface of the petrous part of the temporal bone. The lower part of the jugular process is rough and gives attachment to rectus capitis lateralis. The anterior margin of the jugular process is notched and together with the petrous part of the temporal bone forms the *jugular foramen*. The jugular foramen is a large opening and its size depends much on the size of the jugular fossa on the inferior aspect of the temporal bone. It is oblique in direction being directed upwards, backwards and medially. The floor of the jugular fossa lodges the superior bulb of the internal jugular vein and is separated from the floor of the tympanic cavity by a thin bony lamella. On the lateral wall of the fossa is a minute foramen known as the *mastoid canaliculus* which transmits the auricular branch of the vagus nerve. The jugular foramen is occasionally divided into three compartments, anterior, middle and posterior by two bony spicules. The anterior compartment transmits the inferior petrosal sinus; the glossopharyngeal, vagus and the accessory nerves pass through the intermediate compartment while the posterior compartment transmits the internal jugular vein. In front of the jugular foramen is the outer opening of the carotid canal. The ridge separating the jugular fossa from the carotid opening presents a small opening, the *tympanic canaliculus* which gives entrance to the tympanic branch of the glossopharyngeal nerve.

The *styloid process* projects downwards on the lateral side of the jugular foramen. It gives origin to the styloid group of muscles that is, the styloglossus, the stylopharyngeus and the stylohyoid, and gives attachment to stylomandibular and stylohyoid ligaments. The styloglossus muscle arises from the anterior aspect, the stylohyoid from the posterior aspect while the stylopharyngeus from the medial aspect of the styloid process. The stylomandibular ligament is attached to its lateral aspect while the stylohyoid ligament is attached to its tip. Medially it is related to the internal jugular vein and the internal carotid artery, the stylopharyngeus muscle intervening. Laterally it is covered by the parotid gland. The facial nerve crosses its base while the external carotid artery crosses its tip. Behind the styloid process is the *stylomastoid foramen* which gives exit to the facial nerve and entrance to the stylomastoid branch of the posterior auricular artery.

Postero-lateral to the stylomastoid foramen is the *mastoid process* of the temporal bone which projects downwards and forwards. On its medial aspect there lies the *mastoid notch* (Digastric notch) which gives origin to the posterior belly of the digastric muscle. Further medially close to the occipito-mastoid suture is a vascular groove for the lodgement of the occipital artery. More posteriorly, either lying on the suture between the occipital and the mastoid part of the temporal bone or on the mastoid part of the temporal bone is the *mastoid foramen* which transmits an emissary vein

connecting the sigmoid sinus with the posterior auricular vein. The number of this foramen varies and there may be either one or two foramina in this area.

Behind the foramen magnum the area of the squamous part of the occipital bone is rough and irregular. On the median plane extending from the external occipital protuberance up to the margin of the foramen magnum is a ridge known as the *external occipital crest* which gives attachment to the upper part of the ligamentum nuchae. The area between the inferior nuchal line and the margin of the foramen magnum gives insertion to rectus capitis posterior minor medially and to rectus capitis posterior major laterally. The area between the superior and inferior nuchal lines gives insertion to semispinalis capitis medially and to obliquus capitis superior laterally. The superior nuchal line arches upwards and laterally from the external occipital protuberance. Its medial part gives origin to the highest fibres of the trapezius and its lateral part to occipital belly of the occipito-frontalis muscle and below the latter it gives insertion to sternocleidomastoid and splenius capitis.

NORMA LATERALIS

When the skull is viewed from the sides it is seen to be continuous above with the norma verticalis, behind with the norma occipitalis, although it is demarcated by the salient temporal line; in front and above, it is continuous with the norma frontalis being demarcated by the temporal line, and in front and below, it is separated from the orbit and face by the zygomatic bone. The *temporal line* arches upwards and backwards from the zygomatic process of the frontal bone and soon bifurcates into two lines, *superior* and *inferior temporal lines,* which cross the coronal suture to reach the parietal bone. Running backwards, downwards and forwards from the posterior part of the parietal bone the superior temporal line becomes indistinguishable but the inferior one becomes more prominent and becomes continuous with the posterior root of the zygomatic process of the temporal bone. This portion of the temporal line roughly demarcates the mastoid part from the squamous part of the temporal bone and is known as the *supramastoid crest.* The superior temporal line gives attachment to the temporal fascia while the inferior temporal line marks the upper limit of the origin of the temporalis muscle. The comparatively depressed area below the temporal lines is called the *temporal fossa.*

Temporal fossa. **Boundary.** *Anteriorly* it is bounded by the temporal surface of the zygomatic process of the frontal bone and by the frontal process of the zygomatic bone and to a small extent by the greater wing of the sphenoid. A Y-shaped suture is seen in this area and is formed by the articulation of the frontal, sphenoid and the zygomatic bones. The zygomatico-temporal foramen is seen in this area in the temporal surface of the zygomatic bone and transmits the corresponding vessels and nerves. *Posteriorly* it is bounded by the superior temporal line and the supramastoid crest. *Above* it is bounded by the superior temporal line. *Below* it communicates with the infratemporal fossa under cover of the zygomatic arch. *Below and laterally* it is limited by the zygomatic arch. *Below and medially* it is separated from the infratemporal fossa by the infratemporal crest on the greater wing of the sphenoid and by a line which extends from the infratemporal crest backwards to become continuous with the anterior root of the zygomatic process of the temporal bone.

Bones of the temporal fossa. The bones coming to the formation of the temporal fossa are the frontal, parietal, greater wing of the sphenoid, temporal and the zygomatic. Close to the anterior boundary of the temporal fossa is a Y-shaped suture formed by the articulation of the frontal, greater wing of the sphenoid and the zygomatic bone. More posteriorly an irregular H-shaped suture is marked within the temporal fossa. The vertical limbs of the H-shaped suture are formed by the fronto-sphenoid and fronto-parietal sutures anteriorly and the temporo-sphenoid and the temporo-parietal sutures posteriorly. The horizontal limb being formed by the spheno-parietal suture. This portion of the skull where the four bones namely, frontal, parietal, temporal and sphenoid meet together in the H-shaped

suture is known as *terion*. This is the weakest part of the skull and interiorly the middle meningeal vessels form an intimate relation to this part. Ascending upward from above the external auditory meatus is a vascular groove formed by the middle temporal vessels. Almost the whole of the temporal fossa gives origin to the temporalis muscle.

Contents—
(1) Temporalis muscle
(2) Deep temporal vessels and nerves
(3) Middle temporal vessels
(4) Zygomatico-temporal vessels and nerves

Zygomatic Arch. The zygomatic arch is formed by the zygomatic process of the temporal bone and by the temporal process of the zygomatic bone. It forms the lower and the outer boundary of the temporal fossa and completes a bony tunnel through which the temporal and the infratemporal fossae communicate with each

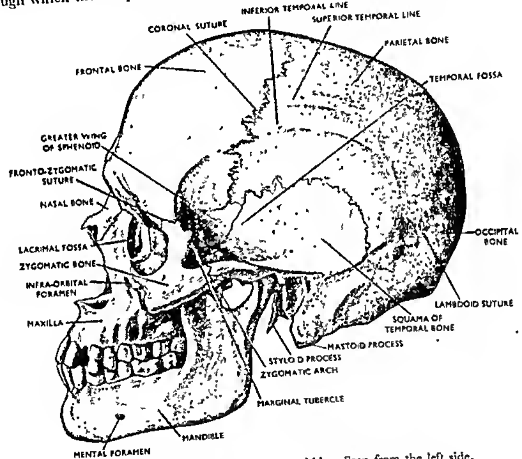


Fig. 429. The skull with the mandible. Seen from the left side.

other. The upper border of the zygomatic arch to its outer part gives attachment to the superficial layer of the temporal fascia and to its inner part on a deeper plane to the deep layer of the temporal fascia. The lower border of the zygomatic arch gives origin to the masseter muscle. The tubercle at the root of the zygomatic process gives attachment to the temporomandibular ligament.

The structures that pass deep to the zygomatic arch are the tendon of temporalis muscle, the anterior and posterior deep temporal vessels and nerves, and the zygomatico-temporal vessels and nerves. The structures that pass superficial to the arch are the auriculotemporal nerve, superficial temporal vessels, temporal branch of the facial nerve and the accessory parotid gland.

Below the posterior root of the zygomatic process of the temporal bone is the opening of the bony external auditory meatus. Its floor and part of the anterior and posterior walls are formed by the posterior surface of the tympanic part of the temporal bone. The outer margin of the bony external auditory meatus is rough and gives attachment to the cartilaginous part of the meatus. Between the postero-superior sector of the bony external auditory meatus and the anterior part of the supramastoid crest is a triangular depression known as the *suprameatal triangle.* Infero-medially this is often bounded by a small bony projection known as the *suprameatal spine.* The suprameatal triangle forms an important bony landmark for the tympanic antrum which lies at a depth of about 1·25 cm. from this.

Behind the anterior root of the zygomatic process is the articular fossa and has already been described.

Infratemporal Fossa. BOUNDARY:

Anteriorly—By the posterior surface of the body of the maxilla.
Posteriorly—It is open.
Medially—It is formed by the pterygoid process (lateral) of the sphenoid.
Laterally—It is open and covered by lateral and medial pterygoid muscles.
Roof—It is formed by the infratemporal surface of the greater wing of the sphenoid and by a small part of squamous temporal.

Contents:

(i) *Muscles*—
(1) Temporalis.
(2) Lateral pterygoid.
(3) Medial pterygoid.
(4) Buccinator.

(ii) *Vessels*—
(1) Maxillary vessels and its branches in this fossa.
(2) Pterygoid venous plexus.

(iii) *Nerves*—
(1) Maxillary nerve.
(2) Mandibular nerve and its branches.
(3) Chorda tympani nerve.

The pterygomaxillary fissure is a triangular gap between the maxilla in front and the pterygoid process of sphenoid behind. It communicates the infratemporal fossa to the pterygopalatine fossa. It gives entrance to the terminal part of the maxillary (Internal maxillary) artery to the pterygopalatine fossa and gives exit to the maxillary nerve from the pterygopalatine fossa.

Pterygopalatine fossa. BOUNDARY:

Anteriorly—By the upper part of the posterior surface of the maxilla.
Posteriorly—By the root of the pterygoid process and the adjoining part of the greater wing of the sphenoid.
Medially—By the upper part of the lateral surface of the perpendicular plate of the palatine bone with its orbital and sphenoidal processes.
Laterally—It communicates with the infratemporal fossa by the pterygo-maxillary fissure.
Roof—It is formed by the undersurface of the body of the sphenoid.
Floor—It is formed by the fusion of the anterior and posterior walls.
Communications—Five openings and two fissures open into the space. Of the five openings three are placed on its posterior wall and in order from above downwards and medially they are the foramen rotundum, pterygoid canal, and the palatinovaginal canal. The sphenopalatine foramen opens into its medial wall while the greater palatine canal opens at the junction of its anterior and posterior walls. It communicates—
(1) By pterygomaxillary fissure—with the infratemporal fossa.
(2) By infraorbital fissure—with the orbital cavity.
(3) By foramen rotundum—with the middle cranial fossa.

(4) By pterygoid canal—with the anterior part of the foramen lacerum.
(5) By palatinovaginal canal—with the roof of the nasal cavity.
(6) By sphenopalatine foramen—with the nasal cavity.
(7) By greater palatine canal—with the roof of the oral cavity.

Contents:

(1) Terminal portion of the maxillary artery with its terminal branches.
(2) Maxillary nerve.
(3) Pterygopalatine (sphenopalatine) ganglion with its branches.
(4) Pterygoid nerve.

NORMA FRONTALIS

The norma frontalis or the skull as seen from the front, is roughly oval in outline and is broader above than below. Above it is formed by the frontal bone where it is smooth. Below the median portion of the frontal bone is the prominence of the bridge of the nose formed by the two nasal bones and by the frontal processes of

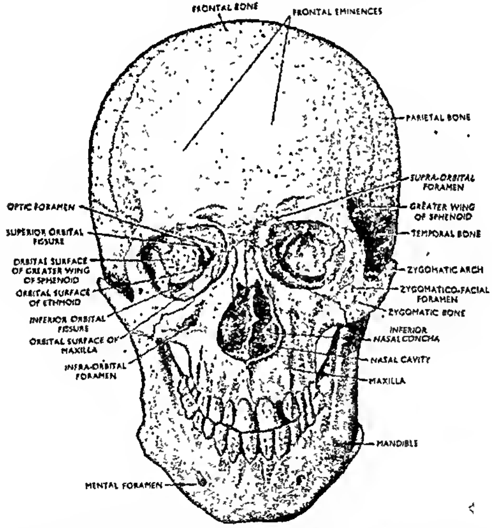


Fig. 430. The skull with the mandible. Seen from the front.

the maxillae. The point on the skull at the junction of the internasal and frontonasal sutures is known as the *nasion*. Above the nasion the smooth elevated area opposite the median plane where the superciliary arches meet together forms the *glabella*. The pear-shaped openings below the bridge of the nose are formed by the

anterior nasal aperture. On either side of the bridge of the nose are the two orbital cavities, one on each side. On either side of the nasal aperture a part of the norma frontalis is formed by the bodies of the two maxillae (anterior surfaces). The alveolar processes of the two maxillae form the upper jaw which contains the upper teeth. Inferiorly the body of the mandible holds the teeth of the lower jaw. Lateral to the orbital opening on either side, the prominence on the face is formed by the zygomatic bone and is known as the *malar prominence*.

THE ORBIT

The orbits are the two funnel-shaped hollow cavities situated one on each side of the nose below the supraorbital margin. The eye-ball with its muscles, vessels, nerves and the lacrimal gland are contained within each orbital cavity which forms a bony socket within which the eye ball rotates. Each orbital cavity consists of a *base*, an *apex*, *a floor*, *a roof* and *medial* and *lateral walls*.

Measurements

Anteroposterior	2 inches.
Vertical (at the base)	$1\frac{3}{8}$ inches.
Horizontal (at the base)	$1\frac{5}{8}$ inches.

The Base. The circumferential margin of the wide mouth of the funnel-shaped orbital cavity forms its base. It is formed by the supraorbital margin of the frontal bone above, the infraorbital margin of the maxilla below, orbital margin of the zygomatic bone laterally and by the anterior lacrimal crest medially.

The Apex. Its apex corresponds to the optic foramen which transmits the optic nerve and the ophthalmic artery.

The Roof. The roof of the orbit is triangular and concave. It is formed by the orbital plate of the frontal bone in front and by the lesser wing of the sphenoid behind. The roof separates the orbital cavity from the anterior cranial fossa. Posteriorly the lesser wing of the sphenoid provides an aperture, the *optic foramen* which transmits the optic nerve and the ophthalmic artery. Midway between the supraorbital notch and the nasolacrimal suture there is either a fovea or a spine, *fovea vel spina trochlearis*, for the attachment of the fibrocartilaginous pulley of the superior oblique muscle of the eye-ball. Antero-laterally it presents a depression, the *fossa for the lacrimal gland* for the accomodation of the lacrimal gland.

The Floor. It is formed mainly by the orbital surface of the maxilla, and a small part by the orbital surface of the zygomatic bone in front and laterally, and by the orbital process of the palatine bone behind and medially. It separates the orbital cavity from the maxillary air sinus. In the medial angle of the floor is the upper opening of the nasolacrimal canal lateral to which a depression on the orbital surface of the maxilla gives origin to obliquus oculi inferior. The infraorbital groove or canal traverses through the middle of the floor and transmits the infraorbital vessels and nerves.

The medial wall. The medial wall of the orbit is quadrilateral in shape and differs from the other walls which are triangular. The medial walls of the two orbital cavities are approximately parallel to each other. It is formed by the frontal process of the maxilla behind the anterior lacrimal crest, the lacrimal bone, the orbital plate of the ethmoid, a small part of the body of the sphenoid in front of the optic foramen, and a small part, by the frontal bone above the bones just enumerated. This wall separates the orbital cavity from the ethmoidal air sinuses and from the anterior part of the sphenoidal air sinus. Behind the anterior lacrimal crest anteriorly there is a groove for the lacrimal sac and behind this, the posterior lacrimal crest gives attachment to the lacrimal fascia and origin to the lacrimal head of the orbicularis oculi. In the frontoethmoidal suture there are the anterior and posterior ethmoidal foramina for the corresponding vessels and nerves.

The lateral wall. The lateral wall is formed by the orbital surface of the zygomatic bone and by the orbital surface of the greater wing of the sphenoid. On the orbital process of the zygomatic bone about 11 mm. below the fronto-zygomatic suture is the orbital tubercle (tubercle of Whitnol) for the attachment of the check

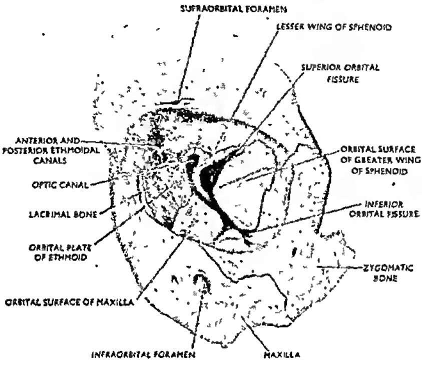


Fig. 431. The bony orbit. Seen from the front.

ligament of the rectus lateralis, part of the aponeurosis of the levator palpebrae superioris, suspensory ligament of the eye-ball and the lateral palpebral ligament. The zygomatico-orbital foramina on this wall transmit the corresponding vessels and nerves. At the junction of the roof and the lateral wall there lies the superior orbital fissure which transmits the oculomotor, trochlear, and abducent nerves and the three branches of the ophthalmic division of the trigeminal nerve, a few filaments *from the cavenous plexus of sympathetic nerves, the orbital branch of the middle* meningeal artery, recurrent meningeal branch of the lacrimal artery and the ophthalmic veins. At the junction of the lateral wall and the floor there lies the inferior orbital fissure which transmits the maxillary nerve, the inferior orbital vessels and nerves, zygomatic nerve and a few filaments from the pterygopalatine (spheno-palatine) ganglion to supply the periosteum of the orbit.

Contents of the orbital cavity. It contains the peripheral organ of sight, (the eye-ball) surrounded by the ocular muscles and fascia, a quantity of fat, a few blood vessels, nerves and the lymphatics of the eye-ball.

INTERIOR OF THE BASE OF THE CRANIUM

When the skull cap is removed the interior of the base of the cranium becomes exposed. From before backwards this side of the skull looks to be most irregular and can be divided into three natural hollows distinct from one another by irregular bony landmarks. These are step-down hollows when looked from before backwards, thus the anterior hollow is on a higher level than the middle one and the latter is on a higher level than the posterior one. The anterior hollow is known as the anterior cranial fossa, the middle—the middle cranial fossa and the posterior—

the posterior cranial fossa. The interior of the base of the cranium forms the floor of the cranial cavity.

THE ANTERIOR CRANIAL FOSSA

The anterior cranial fossa is the highest of all the cranial fossae and it is bounded in front and laterally by the frontal bone; behind by the limbus sphenoidale and by the posterior border of the lesser wing of the sphenoid. Its floor is formed by the cribriform plate of the ethmoid, cerebral surface of the orbital plate of the frontal bone and by the cerebral surface of the lesser wing of the sphenoid. It lodges the inferior aspect of the frontal lobe of the brain being separated by the meninges and the meningeal vessels. For descriptive purposes it may be divisible into a central or median portion and two lateral portions.

Central or median portion. Most anteriorly opposite the median plane on the internal aspect of the frontal bone is a ridge-like elevation formed by the lower end of the *frontal crest* which gives attachment to the anterior end of the falx cerebri containing in between its two layers the superior sagittal sinus. Traced upwards, the frontal crest bifurcates to enclose a longitudinal groove, the *sagittal sulcus*, which lodges the superior sagittal sinus and the margins of the groove give attachment to the two layers of the falx cerebri. Just behind the frontal crest the triangular bony prominence is formed by the *crista galli* of the ethmoid which gives attachment to the anterior end of the falx cerebri. In between the crista galli and the frontal crest is a foramen, the *foramen caecum* which transmits an emissary vein which joins the superior sagittal sinus with the veins of the nasal fossa. On either side of the crista galli and extending backwards behind it, is a perforated plate of bone, the *cribriform plate of the ethmoid* which intervenes between the nasal and the cranial cavities. There are three rows of foramina on it which transmit the olfactory nerves from the nasal cavity, the most medial ones from the septum of the nose, the lateral ones from the lateral wall while the intermediate ones from the roof of the nasal cavity. Posterior to the cribriform plate is a broad relatively flat area formed by the anterior part of the body of the sphenoid and is known as the *jugum sphenoidale* which lodges the gyrus rectus and the olfactory tract on either side of the median plane. Posterior to the jugum sphenoidale is a transverse ridge known as the *limbus sphenoidale* which forms the posterior limit of the anterior cranial fossa. The limbus sphenoidale forms the anterior boundary of a transverse groove known as the *optic groove* which lodges the anterior part of the optic chiasma. The optic groove leads laterally into the *optic foramen* which transmits the ophthalmic artery and the optic nerve, the former lying inferolateral to the latter.

Lateral portions. The two lateral portions of the anterior cranial fossa, one on each side of the median portion, are formed mostly by the orbital plate of the frontal bone and partly by the lesser wing of the sphenoid. The orbital plate is marked by irregular impressions for the lodgement of the gyri on the inferior aspect of the frontal lobe of the brain and is also marked by vascular impressions for the meningeal vessels. The orbital plate separates the anterior cranial fossa from the orbit as well as from the ethmoidal air sinuses. On either side of the cribriform plate it overlaps the superior aspect of the labyrinth of the ethmoid and thus completes the upper wall of the ethmoidal sinuses. Roughly opposite the middle of the ethmoidal labyrinth is a foramen which leads to a canal, the anterior ethmoidal canal, which connects the anterior cranial fossa with medial wall of the orbit and transmits the anterior ethmoidal vessels and nerves. Posterior to the opening of the anterior ethmoidal canal at the posterior part of the ethmoidal labyrinth is the opening of the *posterior ethmoidal canal* which also opens on the medial wall of the orbit and transmits the posterior ethmoidal vessels. Lying behind the orbital plate of the frontal bone is the lesser wing of the sphenoid which overhangs the superior orbital fissure and the middle cranial fossa and ends into a rounded border posteriorly. It forms the posterior border of the lesser wing of the sphenoid which in the recent state fits into the lateral cerebral fissure. On its inferomedial part it lodges the

sphenoparietal sinus. Traced medially this border ends into a rounded process known as the *anterior clinoid process* which gives attachment to the anterior end of the free border of the tentorium cerebelli. The lesser wing is attached to the body of the sphenoid by two roots which enclose between them the optic foramen.

THE MIDDLE CRANIAL FOSSA

The middle cranial fossa consists of a central or median elevated area and two lateral hollows, one on each side of the central portion.

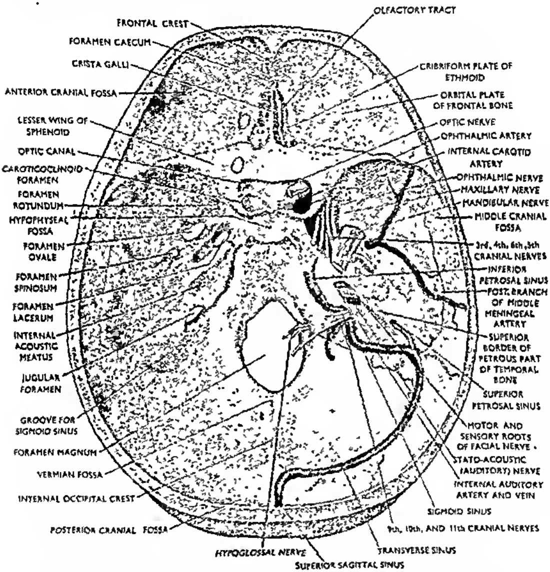


Fig. 432. The internal aspect of the base of the cranium showing the features on the left side and the structures that leave and enter into the cranial cavity through the different openings of communication on the right side.

Central or median portion. The central or median portion of the middle cranial fossa is formed by the body of the sphenoid. It is bounded in front by the limbus sphenoidale and bounded behind by a square plate of bone known as the *dorsum sellae.* Just behind the limbus sphenoidale is a transvese groove, the *optic groove* which lodges the anterior part of the optic chiasma. The optic groove leads laterally into the *optic foramen* which transmits the optic nerve and the ophthalmic artery. Behind the optic groove is a rounded elevation known as the *tuberculum sellae.* The

inconspicuous bony projections on either side of it (lying on a more posterior plane) are formed by the *middle clinoid processes* which are occasionally joined with the anterior clinoid processes by a bony process and a foramen is formed on each side known as the *carotico-clinoid foramen* which transmits the internal carotid artery. The tuberculum sellae together with the middle clinoid processes forms the anterior boundary of a deep depression known as the *sella turcica* or the *hypophyseal fossa* which lodges the hypophysis cerebri or the pituitary body. Postero-superiorly the sella turcica is overhung by a square plate of bone known as the *dorsum sellae*. The supero-lateral corners of the dorsum sellae form rounded bony processes known as the *posterior clinoid processes*. The posterior clinoid process gives attachment to the anterior end of the attached border of the tentorium cerebelli. Lower down on either side of the dorsum sellae is a groove which lodges the commencement of the inferior petrosal sinus. The gap between the dorsum sellae and the tuberculum sellae is bridged over by a process of duramater in the recent state known as the diaphragm sellae which has a central hole for the transmission of the stalk or the infundibulum of pituitary body. The stalk of the pituitary body connects the latter with the floor of the third ventricle of the brain. On either side, the central portion of the middle cranial fossa which is formed by the body of the sphenoid, becomes continuous with the lateral hollows and at the junction of the two is a wide anteroposterior groove known as the *carotid sulcus* which lodges the cavernous sinus containing within it the internal carotid artery, ophthalmic, oculomotor, trochlear and abducent nerves. The central point of the cavernous sinus corresponds to a point externally on the upper border of the zygomatic arch opposite the tubercle at the root of the zygoma.

Anteriorly the central portion of the middle cranial fossa is separated from the nasal cavity by the intervening sphenoidal air sinus contained within the body of the sphenoid.

LATERAL PART OF MIDDLE CRANIAL FOSSA

Each lateral part of the middle cranial fossa forms a deep hollow chamber on each side of the median elevated portion. Each chamber contains the temporal lobe of the brain and is formed by the greater wing of the sphenoid, and squamous and petrous parts of the temporal bone. It is bounded in front by the lesser wing of the sphenoid and behind by the superior border of the petrous part of the temporal bone; laterally by the squamous temporal, greater wing of the sphenoid, and above the former by the parietal bone; medially it becomes continuous with the fellow of its opposite side across the elevated central part of the middle cranial fossa. Anteriorly each lateral hollow is related to the orbital cavity, laterally to the temporal fossa, the bony wall intervening, and inferiorly to the infratemporal fossa being separated by the bone on the floor of the fossa (greater wing of sphenoid).

Anteriorly each lateral part is communicated to the orbital cavity by an oblique fissure known as the *superior orbital fissure* which intervenes between the greater and lesser wings. The superior orbital fissure transmits the oculomotor, trochlear and abducent nerves, the three branches of the ophthalmic division of the trigeminal nerve (frontal, lacrimal and nasociliary) and the orbital branch of the middle meningeal artery from cranial to the orbital cavity, and from orbital to the cranial cavity, the recurrent meningeal branch of the lacrimal artery and the ophthalmic veins. Just behind the superior orbital fissure is a rounded foramen known as the *foramen rotundum* which communicates the middle cranial fossa with the pterygopalatine fossa and transmits the maxillary nerve. Behind the foramen rotundum at a distance of about 1.25 cm. from it, close to the posterior border of the greater wing of the sphenoid, is the *foramen ovale* which communicates the middle cranial fossa with the infratemporal fossa and transmits the mandibular nerve, accessory meningeal artery and sometimes the lesser superficial petrosal nerve. Lateral to the foramen and medial to the spine of the sphenoid is a small rounded foramen, the *foramen spinosum* which transmits the middle meningeal artery and the meningeal branch of mandibular nerve. The trunk of the middle meningeal artery after enter-

ing the cranial cavity is lodged in a groove which extends forwards, laterally and upwards from the foramen spinosum across the squamous part of the temporal bone up to a point on the upper border of the zygomatic arch externally midway between the outer margin of the orbit and the internal auditory meatus. Beyond this point the groove bifurcates into anterior and posterior branches which are occupied by the anterior and posterior branches of the artery respectively. The groove for the anterior branch ascends as far as the point of terion to reach the antero-inferior angle of the parietal bone where the groove is deeper and occasionally forms a bony tunnel. The course of the groove further ascends towards the vertex giving out branches corresponding to the branches of the anterior division of the middle meningeal artery and finally reaches a point on the vertex midway between the nasion and the inion. The posterior branch of the groove starts at the point of bifurcation of the groove for the main trunk of the artery and then ascends upwards and backwards to a point corresponding with lambda. At the medial end at the apex of the petrous part of the temporal bone and intervening between it and the body of the sphenoid is a large irregular aperture, the *foramen lacerum* which in the recent state is filled up by a plate of cartilage which is usually pierced by the meningeal lymphatics, meningeal branch of the ascending pharyngeal artery and occasionally by an emissary vein. It lodges the internal carotid artery, together with its plexus of sympathetic nerve in its course to the carotid sulcus on the side of the body of the sphenoid, the deep petrosal nerve, the greater superficial petrosal nerve and the nerve of the pterygoid canal formed by the union of the last two nerves. Immediately lateral to the apex of the petrous part of the temporal bone is a depressed area on the anterior surface of the petrous part known as the *trigeminal impression* for the lodgement of the semilunar ganglion of the trigeminal nerve. Postero-lateral to it is a ridge and then a depressed area which roofs in the internal auditory meatus and the cochlea. Further postero-laterally is an eminence, the *arcuate eminence* formed by the superior semicircular canal of the internal ear. Intervening between the anteiror surface of the petrous part and the squamous part is a thin plate of bone known as the *tegmen tympani* which roofs both the tympanic cavity and the tympanic antrum. On it, antero-medially, placed side by side, are two small openings for the greater and lesser superficial petrosal nerves and are known as the hiatus for greater and lesser superficial petrosal nerves respectively, the former being medial to the latter. The superior border of the petrous part which forms the posterior boundary of the lateral part of the middle cranial fossa, presents a groove for the lodgement of the superior petrosal sinus. The margins of the groove give attachment to the two layers of the tentorium cerebelli.

THE POSTERIOR CRANIAL FOSSA

The posterior cranial fossa is the deepest and the largest of all the cranial fossae and contains the cerebellum, pons and the medulla oblongata. The foramen magnum which communicates the posterior cranial fossa with the veteberal canal forms the most conspicuous feature and the most dependent part of the posterior cranial fossa. The bones coming to the formation of this fossa are the posterior part of the body of the sphenoid, the basilar and condylar parts and the squamous part up to the level of the internal occipital protuberance of the occipital bone, the mastoid part and the posterior surface of the petrous part of the temporal bone, and a small part by the postero-inferior angle of the parietal bone.

Anteriorly it is bounded by the dorsum sellae, the posterior part of the body of the sphenoid and by the basilar part of the occipital bone; *posteriorly* by the squamous part of the occipital bone below the level of the internal occipital protuberance; laterally it is bounded by the petrous (posterior surface) and the mastoid parts of the temporal bone, a small portion of the postero-inferior angle of the parietal bone and by the condylar part of the occipital bone.

For purposes of description the posterior cranial fossa can be divisible into three parts—median or central portion and two lateral portions—one on each side of the central portion.

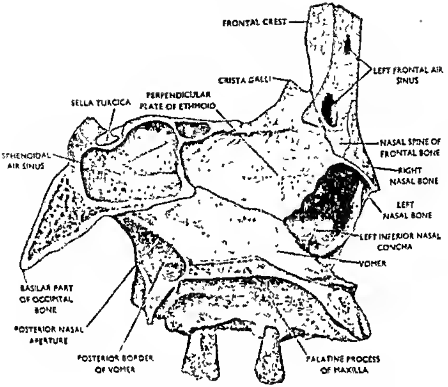


Fig 433. A paramedian section to show the bony nasal septum.

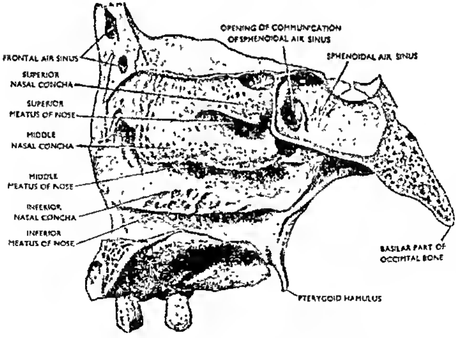


Fig 434. A paramedian section of the skull to show the right lateral wall and floor of the nasal cavity.

Each nasal concha hides a space on its lateral aspect known as the meatus and from above downwards there are the superior, middle and the inferior meatuses of the nose.

The *superior meatus* of the nose is situated at the upper and posterior part of the lateral wall and is roofed by the superior nasal concha. The posterior ethmoidal air cell opens into it. The superior nasal concha is separated posteriorly from the anterior surface of the body of the sphenoid by a narrow recess known as the spheno-ethmoidal recess into which the sphenoidal air sinus opens.

The *middle meatus* of the nose lies under cover of the middle nasal concha and intervenes between the superior and inferior nasal conchae. Anteriorly it is prolonged upwards into a narrow passage known as the *infundibulum* into which the frontal and the anterior ethmoidal air sinuses open. The middle ethmoidal air cell projects into this meatus to form a rounded swelling known as the *bulla ethmoidalis* and opens into it. Into its middle part the maxillary air sinus opens.

The *inferior meatus* of the nose is the longest of all and is hidden from view by the inferior nasal concha. At its anterior part the naso-lacrimal canal ends which contains the naso-lacrimal duct in the recent state.

The ANTERIOR NASAL APERTURE is pear-shaped being broader below than above and opens into the face. It is formed by the nasal bone and the maxilla.

The POSTERIOR NASAL APERTURE communicates each nasal cavity to the nasal part of the pharynx and through the latter to each other. It is bounded above by the undersurface of the body of the sphenoid, below by the horizontal plate of the palatine bone, medially by the posterior part of the vomer and laterally by the medial surface of the medial pterygoid plate.

ARTICULAR SYSTEM OR ARTHROLOGY

In an analysis of the skeletal frame-work of the bodies of animals including man it is observed that numerous bones of various shapes and sizes come to the formation of the skeleton and that they (bones) are variously united together to form "joints". Thus the whole skeleton is built up on a joint-system in which the participating bones or cartilages in a particular joint are either immovably united together or they are united in such a way that spaces are left between the participating members of the joint so as to allow movement between themselves.

The mechanics of joints. The mechanism in a joint varies with the functions of the joint. In an immovable joint the bony contour of the surfaces of the articulating bones is rough and irregular and the apposed surfaces are united together by either fibrous bands or by cartilages and there is no space between the articulating bones. Additional fibrous bands known as *ligaments* connect the articulating bones at their free surfaces to make the joint well-secured and fixed. These joints are meant for providing either a rigid frame for other movable attachments (joints) in connection with them or they provide a larger mass for movement as a whole of the particular part of the body or they provide a larger surface area for attachment of the soft parts.

In a movable joint the mechanism is quite different. The bony contour of the surfaces of the articulating bones are usually smooth and regular; there is a joint cavity between the articulating bones which permits sufficient movement between them; by virtue of their mobility these joints are less unsound in their stability. Ligaments form the basis of connection between the articulating bones. Muscles are superimposed over the ligaments in most cases to provide additional support and power for movements. Depending on the nature of the joint the movements occur in a particular axis or in different axes. In most joints the movements take place on the engineering principles of "lever action".

"Lever Action". Any movement that takes place with the help of a "lever" is called the "lever action". A mechanical lever consists essentially of a rigid bar, straight or bent, which has one fixed point about which the rest of the lever moves. The fixed point is called the *fulcrum* while the perpendicular distances between the fulcrum and the lines of actions of effort and the weight are known as the arms of the lever.

Mechanically three classes of levers can be identified such as class I, class II and class III levers which increase the efficiency of movement in the descending order.

Class I lever. With this type of lever the movement is very free even with least effort. Here the fulcrum is between the lines of action of weight and the effort. In the accompanying diagram it may be noted that the effort E and the weight W act on opposite sides of the fulcrum F.

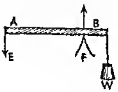


Fig. 435. First class lever.

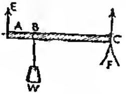


Fig 436. Second class lever.

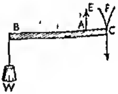


Fig. 437. Third class lever.

Class II lever. These types of levers work with some mechanical disadvantage for which greater effort is necessary for a particular movement. Here the lines of effort and the weight act on the same side of the fulcrum but the line of effort is at a greater distance than the line of the weight. It may be noted in diagram 436 that the effort E and the weight W act on the same side of the fulcrum F but the former acts at a greater distance than the latter from the fulcrum F.

Class III lever. In these levers the movement is executed at the expense of a still greater effort than the class II levers. Here also both the lines of effort and weight lie on the same side of the fulcrum but the line of the effort is at a lesser distance than the line of the weight from the fulcrum (*vide* diagram 437).

SUBDIVISIONS OF THE JOINTS

In order to study the joints, and for convenience of description, joints may be classified in either of the two ways, according to the nature of the connecting medium or according to the functions:

(A) According to the nature of the connecting medium:

(1) Fibrous.
(2) Cartilaginous.
(3) Synovial.

FIBROUS JOINTS

In **fibrous joints** the bones entering into the articulation are connected together through the medium of fibrous tissue and functionally they are immobile. The fibrous joints may further be subdivided into sutures, gomphosis and syndesmosis.

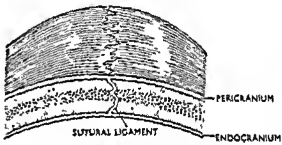


Fig. 438. The sutural joint.

Sutures. Sutures are only peculiar to the cranial bones where articulating bony edges are firmly interlocked to each other and are joined together by a thin layer of fibrous tissue known as the *sutural ligament.* According to the nature of the articulating margins of the bones the sutures are further divided into the following sub-groups:

(*a*) *Sutura serrata.* In sutura serrata the bones articulate with each other by serrated margins as in the articulation between the two parietal bones (sagittal suture).

(*b*) *Sutura denticulata.* In this variety of suture the bones articulate with each other by tooth-like processes as in the articulation between the mastoid part of the temporal bone and the occipital bone.

(*c*) *Sutura squamosa.* In this, two bones articulate with each other by bevelled margins which overlap each other. The example for this is seen in the articulation between the squamous part of the temporal bone and the parietal bone.

(*d*) *Sutura limbosa.* It is a serrated suture whose margins overlap each other.

(*e*) *Sutura plana.* In plane sutures two bones articulate with each other by simple apposition as between the horizontal part of the palatine bone and the palatal process of the maxilla.

(*f*) *Schindylesis.* Schindylesis or a wedge and a groove joint froms a variety of cranial articulation where a bony wedge fits into a groove, as for example the articulation between the rostrum of sphenoid and the fissure between the alae of the vomer.

Gomphosis. This is also peculiar to the cranial articulation; here the articulation takes place by insertion of a peg into a socket, as for example, the articulation between the tooth and its socket.

Syndesmosis. In this subgroup of the fibrous joints the opposed bony surfaces articulate with each other by an **interosseous** ligament, as for example, the inferior tibio-fibular syndesmosis.

CARTILAGINOUS JOINTS

In **cartilaginous joints** the opposed bony surfaces are joined together by means of an intervening cartilage. **Functionally** these joints are either absolutely immobile or only partially mobile. Cartilaginous articulations form two distinct varieties and are sub-grouped into primary and secondary cartilaginous joints.

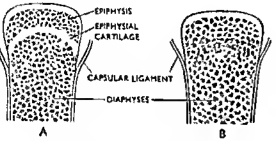


Fig. 439 Primary cartilaginous joint.

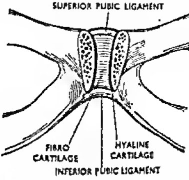


Fig. 440. The symphysis pubis, a variety of secondary cartilaginous joint.

Primary cartilaginous joints. These are the articulations where the opposed bony surfaces are united together by means of a cartilage which later on undergoes ossification and the two different bony parts entering into the articulation no longer exist as separate units but they become osseously continuous with each other, as for example, the union between the epiphysis and the diaphysis of a long bone. No movements are permitted in these joints.

Secondary cartilaginous joints. Here the intervening cartilage remains patent throughout life, as for example, the articulation between the two vertebrae or the articulation between the two pubic bones (symphysis pubis). Limited range of movements is permitted in these joints.

SYNOVIAL JOINTS

Of all the joints the **synovial joints** are most mobile and the bones entering into the articulation are primarily joined together by a capsular ligament which is lined internally by the synovial membrane.

Characters of synovial joints:

(1) The bones entering into the articulation are completely surrounded by capsular ligament which is lined internally by the synovial membrane.
(2) The bony ends entering into the articulation are covered with articular cartilage.
(3) Within the synovial lining there is always a potential space known as the joint cavity.
(4) The joint cavity may be completely subdivided into two compartments by an intervening articular disc or there may be intra-articular cartilage or menisci.
(5) All synovial joints are characterised by their extreme mobility.

Synovial membrane. Up to the fourth month of intrauterine life a diarthrodial joint cavity is completely lined by a stratum of mesenchymatous tissue which not only covers the inner aspects of the capsular ligament but also covers the articular

cartilages entering into the formation of the joint. Later on, the synovial membrane differentiates from this layer of mesenchymatous tissue. During fifth month of intrauterine life when active intrauterine movement begins, the synovial membrane lining the articular cartilages becomes rubbed off due to pressure and friction. At birth, the synovial membrane still encroaches to a slight extent on the margins of the articular cartilage but soon it disappears from there with the institution of greater range of movement.

Distribution. The synovial membrane lines the interior of the capsular ligament. In places where the capsular ligament is attached to the bone at some distances from the articular cartilage, as in the upper end of the femur, it also lines the bone between the capsular ligament and the articular cartilage. It also invests the intra-articular structures, such as the long tendon of the biceps brachii in the shoulder joint and the cruciate ligaments in the knee joint; it also covers the sub-synovial pads of fat which project into the joint cavity. It may be thrown into folds to form synovial *villi*. Occasionally a bag of synovial membrane comes out through some opening in the capsular ligament and acts as a bursa for the neighbouring muscle.

Depending on the tissues on which the synovial membrane lies the latter shows variation in structure and on this basis it is often classified into *fibrous*, *areolar* and *adipose types*.

Areolar type. It covers those parts of the joint which are not subjected to strain or pressure. Structurally it consists of a deep layer of loose connective tissue and a surface layer of collagenous fibres interspersed with fibroblasts, macrophages, leucocytes and wandering cells.

Fibrous type. It covers those parts of the joints which are subjected to strain and pressure and also it covers the intra-articular ligaments and tendons. Structurally it consists of deeper dense connective tissue and a more cellular surface layer of cells.

Adipose type. It covers the subsynovial pads of fat which project into the joint cavity. Structurally it consists of a single layer of cells on the surface and a deeper thin connective tissue layer.

Structure. The synovial membrane consists of three layers, a thin layer of loose, cellular connective tissue which lines the articular capsule, a layer of flattened or polygonal cells (Synovial cells) which lie on the free surface and a layer of network of small blood vessels which lies beneath the surface layer of cells.

The cells over the free surface are modified connective tissue types and are not of mesothelial types as was known before. The loose, cellular, connective tissue layer consists of some thin collagenous fibres, a few elastic fibres and a large number of different types of connective tissue cells (fibroblast, mast cells, plasma cells, histiocytes, mesenchyme cells, pigment cells).

Function. The synovial membrane is concerned in absorption from the joint cavity and this is more manifested where it covers the loose connective tissue and the subsynovial pads of fat. Over the subsynovial pads of fat it is often reduplicated and the cells over them are often thrown into small complicated folds which have some appearance of the villi. In some of the diarthrodial joints, specially in the knee-joint, this arrangement is conspicuously marked and thus allows a very rapid absorption which readily accounts for the occasional appearance of septicemia in acute traumatic infections of this joint. Experimentally it has been repeatedly shown that absorption is greatly accelerated with movement of the joint. This fact obviously affords important bearing on the treatment of chronic arthritis with effusion of fluid into it.

The synovial membrane secretes a glairy synovial fluid which effectively lubricates the articular surfaces and thereby prevents gross friction.

The synovial fluid secreted by the synovial cells provides nutrition to the articular cartilage of the joint.

Subsynovial pads of fat serve mechanically for the purpose of filling up the changing spaces which occur during movement of a joint. As for example, the subsynovial pad of fat of the olecranon fossa which, when the elbow is flexed, fills

up the olecranon fossa by the pressure of the triceps whereas during extension it i filled up by the olecranon process.

The synovial cavity may be in communication with the bursal sacs in th. neighbourhood of the joint.

Articular cartilage. The articular cartilage of the bony ends of a diarthrodial joint is of the hyaline variety and presumably this is the persistent unossified layer of cartilage from which the whole of the bone has been developed. This hyaline articular cartilage is completely avascular and is devoid of any nerve supply. It has neither a perichondrium nor a synovial covering. It presents a smooth glistening appearance and is kept lubricated by the synovial fluid.

Structurally the articular cartilage consists of several layers of cartilage cells and those covering the surface are of flattened types while those overlying the bone show signs of calcification. The presence of flattened type of cells in the surface area indicates degeneration and gradual disintegration of the cells of this area and presumably these cells are continually replaced by proliferation of the cells of the intermediate layer.

Nutrition of articular cartilage. From the point of view of reparative power and its reactions to irritants the articular cartilage may be divided into peripheral and central parts which differ in their source of nutrition. The peripheral portions of the articular cartilage being in close proximity to the vascular synovial membrane derive their nutrition from the same while its central portion derives its nutrition from the synovial fluid.

Experimental works done by Fisher show that when the peripheral portion of the articular cartilage is damaged experimentally it is completely regenerated and replaced by formation of new cartilages whereas when the central portion is incised it is replaced by formation of fibrous tissue. Clinically in some chronic arthitis, the articular cartilage is also completely destroyed due to toxic influences and its peripheral portion regenerates by active growth while its central portion remains eroded and thus forms 'lipping' of the articular margin.

That the synovial fluid provides nutrition for the articular cartilage is proved by the observation that isolated fragments of articular cartilage, which have been detached by injury and lie free in a joint cavity, not only survive but also show signs of continual growth. Such detatched surviving cartilage within the joints is popularly known as "joint mouse".

Intra-articular menisci. In some synovial or diarthrodial joints, discs or menisci of fibrocartilage are found to be interposed between the articular surfaces of the bones. In some, they are complete as in the temporomandibular and sternoclavicular joints, and they completely separate the articular surfaces on the bones, while in some others, they are deficient centrally and are semilunar or rounded in shape i.e., the semilunar cartilages of the knee joint. Developmentally they are the persistent organised portions of the embryonic articular discs which are usually found in all synovial or diarthrodial joints.

Functionally they serve to compensate for the incongruity of articular surfaces between which they are interposed. They also act as buffers in minimizing the shock of impact between the articular surfaces.

The menisci are supplied with nerves which maintain some sensory functions in that with rapid pressure changes within the joint these nerves form a basis of a reflex arc in which rapid muscular control of the joint is brought about.

It is interesting to note that semilunar cartilages of the knee-joint are capable of rapid regeneration after operative removal of the same. The process of regeneration is supposed to be the result of a cellular reaction in the synovial membrane which leads to the production of dense fibrous tissue and thereby forms the basis of a new menisci.

Subdivisions of synovial or diarthrodial joint. Synovial joints or diarthroses are divided into different sub-groups according to the nature of movement permitted in such joints. The following varieties may be noted.

(*a*) *Enarthrosis or ball and socket joint.* In this a spheroidal articular surface articulates with a concavity which forms the socket. All sorts of movements, i.e., flexion, extension, adduction, abduction, rotation and circumduction, are permitted in these joints. Examples—shoulder and hip joints.

(*b*) *Condylarthrosis or condyloid joint.* In this variety of synovial joints the articular surfaces are more conspicuously ellipsoid and the movement of flexion, extension, adduction, abduction, etc. are permitted but no active rotation takes place. Examples—wrist joint, metacarpophalangeal joint, etc.

(*c*) *Saddle joint.* In this variety of joints the articular surfaces are concavo-convex in opposite direction. Movements in this joint are complicated, and flexion, extension, adduction, abduction with slight rotatory movements may take place in this joint. Examples—carpometacarpal joint of thumb.

(*d*) *Ginglimus or hinge-joint.* In this variety of joints movement only takes place about a transverse axis, that is, flexion and extension. Examples—elbow joint, interphalangeal joints.

(*e*) *Trochoid or pivot joint.* This type of joint only allows movement about a longitudinal axis, i.e. rotation. Examples—superior radio-ulnar joint and the articulation between the first and second cervical vetebrae.

(*f*) *Arthrosis or plane joint.* In this only some sort of gliding movement is permitted. Examples—intercarpal and intertarsal joints.

(B) Sub-divisions of the joints according to the movement:

(1) Synarthrosis
(2) Amphiarthrosis
(3) Diarthrosis

(1) *Synarthrosis or immovable joints.* Under this sub-group the sutures of the fibrous joints and the primary cartilaginous joints are included.

(2) *Amphiarthrosis or slightly movable joint.* Limited range of movements is permitted in these joints and they include the syndesmosis of the fibrous joint and the secondary cartilaginous joints.

(3) *Diarthrosis or freely movable joints.* These joints are extremely mobile and all of them fall under the sub-group of the synovial joint.

Development of joints. The series of events in a developing joint can better be understood in following the changes in a developing limb bud. Structurally the earliest limb bud is a bag of ectoderm tightly filled-in with a mass of undifferentiated mesenchymal tissue. With the growth of the limb bud, the central mesenchymal tissue becomes condensed and at first becomes segmented into three parts corresponding to the three main portions in each limb bud (arm, forearm and hand in the upper limb, and thigh, leg and foot in the lower limb) and between the two condensed portions there intervenes a plate of undifferentiated mesenchymal mass. The condensed mass subsequently develops into cartilage which is surrounded by the perichondrium. The perichondrium of one segment is continuous with the perichondrium of the other and the plate of undifferentiated mesenchyme intervenes between the segments being attached at its circumferential margin to the bridging perichondrium. The bridging perichondrium that connects the two cartilaginous segments constitutes the *primary capsule* and the undifferentiated mesenchymal disc between the two constitutes the *joint disc.*

Subsequently, changes take place in the mesenchymal joint disc and at the same time the cartilaginous segments become ossified and the perichondrium becomes the periosteum. Depending on the subsequent function, the mesenchymal joint disc is either converted into fibrous tissue or into a fibrocartilage or it undergoes liquefaction to form a joint cavity. Where the joint disc is converted into fibrous tissue the latter connects the two segments of the developing bone and the resulting joint is a *fibrous joint.* In a similar way the *secondary cartilaginous joint* is developed—the joint disc becomes a fibrocartilage. The *primary cartilaginous joint* is associated with a developing long bone.

By the tenth of week of foetal life the joint discs in the synovial joints begin to liquefy and break down at their periphery to form cavitation. The cavity then extends towards the centre and a *joint cavity* is formed which is at first small and irregular. Ultimately the whole disc is replaced by a cavity except a thin layer of

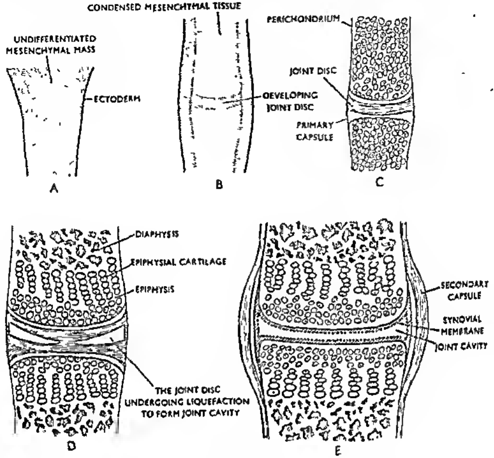


Fig. 441. The stages in the development of a joint.

disc mesenchyme which overlies the bony ends entering into the articulation and the inner aspects of the capsule. This persisting thin layer of the disc mesenchyme becomes flattened to form the *synovial membrane.* Subsequently, due to pressure and friction, the synovial membrane overlying the opposed surfaces of the bony ends disappears.

Blood Sopply of joints. All joint-structures except the central portions of the hyaline articular cartilages are supplied by the *periarticular anastomoses* and by the *circulus vasculosus.* Offsets from these vessels supply the adjacent bones as well as the other joint-structures. Some of these vessels pierce the articular capsule in the synovial joints and form a rich network in the synovial membrane where they run into capillary bed. Some of these capillaries lie just beneath the free surfaces of the membrane and this accounts for the occasional effusion of blood in the joint cavity that often occurs after injury to a particular joint.

Periarticular anastomoses. Around each joint, particularly around the joints of the limbs, arteries anastomose freely with one another forming what is known as periarticular anastomosis. This type of free anastomoses around a joint is responsible for the efficient collateral circulation, in case, some of the arteries are blocked or damaged as a result of injuries in the form of fracture or dislocation of a particular 'nt.

Circulus vasculosus. It is a definite form of periarticular arterial circle that surrounds a joint and lies between the capsular ligament and the synovial membrane at their attachment to the bone.

In a growing bone where the epiphysis is still cartilaginous, no blood vessels are seen to grow into the epiphysis except during the process of ossification. At this stage the epiphyseal plate forms a barrier between the epiphyseal arteries and the metaphyseal ones, which are end arteries, derived from the nutrient artery of the shaft. With the union of the epiphysis with the diaphysis the two arterial systems become continuous with each other and the metaphyseal vessels no longer form end-arteries. The presence of the end-arteries in a young bone predisposes the occurrence of osteomyelitis in the region of the metaphysis but in the adult, there being no end-arteries in the region of the metaphysis, osteomyelitis does not occur selectively in the region of the metaphysis.

Lymphatics of joints. Fine lymphatic vessels are found to exist as lymphatic plexuses within the synovial membrane which drain into larger lymph vessels and ultimately they end into the regional lymph nodes.

Nerve Supply of joints. Joints are supplied by both *cerebrospinal* and *autonomic nerves.* All the tissues of the joints, except perhaps the articular cartilage, are supplied by nerves which may come from a single source or from different sources. When the nerves are multiple each nerve supplies a particular zone of the joint with some amount of overlapping with one another.

In a moving joint the nerve that supplies a particular zone of the capsular ligament also supplies the muscle that prevents overstretching of the same zone of the joint capsule. This is an autonomous protective mechanism for the joints in which, when a particular part of the joint capsule is put on stretch, its "muscular counterpart" contracts sufficiently to prevent over-stretching through reflex-action.

The functional components of the articular nerves or the neural mechanism of the joints. Functionally the articular nerves consists of *protective, proprioceptive* and *trophic components.* The protective components are concerned in safeguarding the integrity of the joint-structures as explained above. The proprioceptive fibres are concerned in conveying impulses about the internal condition of the joint to the higher centre for its governing the joint activities in respect of postures and movements. The trophic components are in someway concerned in the nourishment and well-being of the joint.

Hiltons's Law. A nerve that supplies a joint also supplies the muscles moving the joint and the skin over the insertions of the same muscles.

Vital re-actions of joint structures. With the alterations in function the joint-structures re-act actively to adapt to the new condition. Thus when a movable joint is immobilised for some time continuously or its movements are limited upto a certain range, the aricular capsule and the other ligaments shorten to such an extent as to fix the joint in the same position in which it was immobilised. The articulating surfaces may be fused together by the ingrowth of the vascular connective tissue from the periphery. If the condition is permitted to continue, the articular cartilages suffer a change in structure in which they are converted into fibrous tissue. It also shows adaptive changes with movements. As for example, when a particular movement is extended in a particular direction the articular cartilage also extends to that direction.

When an articular cartilage is injured it fails to show regenerative changes and is repaired by fibrous tissue. When a fragment of an articular cartilage is detatched and lies within the joint, it survives and grows by the synovial fluid within the joint.

VERTEBRAL JOINTS

The vertebral column forms a pillar by joints and each vertebra from second cervical to the fifth lumbar articulates with the succeeding vertebra by two joints,

one between the bodies of the two contiguous vertebrae and another between their vertebral arches.

Articulation between the bodies of the two vertebrae. The bodies of the two vertebrae articulate with each other through the medium of an intervertebral disc. The intervertebral disc separates the two vertebrae from each other and remains distinct throughout life and hence the *joint formed by the bodies of the two vertebrae is a secondary cartilaginous joint*. The ligaments of the joint are the anterior and the posterior longitudinal ligaments.

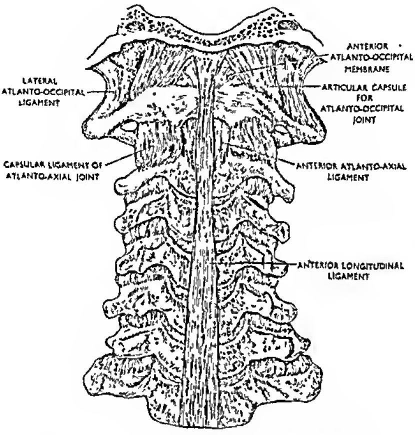


Fig. 442. The atlanto-occipital, the atlanto-axial and the joints of the vertebrae of the cervical region. Viewed from the front.

Anterior longitudinal ligament. The anterior longitudinal ligament is the common anterior ligament for all the vertebrae and forms a thick ribbon-like fibrous band which connects all the vertebrae and the intervertebral discs together anteriorly. It extends from the anterior aspect of the second cervical vertebra to the anterior aspect of the body of the first sacral vertebra. In its course it is firmly adherent to the intervertebral discs and to the upper and lower margins of the vertebrae. Opposite the centre of each vertebral body it is loosely attached and is easily separable from it. Superiorly it is continuous with the anterior atlanto-occipital membrane. Inferiorly it ends by fusing with the periosteal covering in front of the first sacral vertebra. It is thickest in the thoracic region and widest in the lumbar region.

Posterior longitudinal ligament. It covers the posterior aspects of the bodies of the vertebrae and has similar attachment like the anterior longitudinal liga- Superiorly it is continued upwards beyond the second cervical vertebra and as

it extends upwards it becomes broad and membranous which covers the back of the odontoid process of the axis and then passing through the foramen magnum it is attached to the superior aspect of the basilar part of the occipital bone. This portion of the posterior longitudinal ligament which extends upwards from the back of the

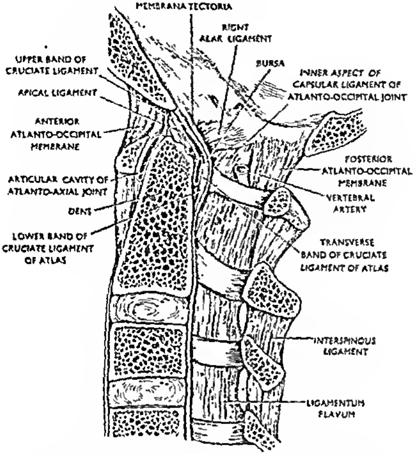


Fig. 443. A mid-sagittal section through the occipital bone and the upper four cervical vertebrae to show the connections between the cervical vertebrae, between the atlas and the occipital bone and between the axis and the occipital bone.

axis to the basilar part of the occipital bone is known as the *membrana tectoria*. Inferiorly it invests the sacral canal anteriorly and extends to the first piece of the coccyx as the deep posterior sacro-coccygeal ligament.

Intervertebral disc (see also vertebral column). The intervertebral disc is a fibro-cartilaginous plate which intervenes between two adjacent vertebrae. It is wanting in between the atlas and the axis because there is no body of the atlas; the last intervertebral disc lies between the fifth lumbar and the first sacral vertebrae. It varies in thickness in the different regions of the vertebral column and also in the same disc in its different portions. Its size and shape correspond to the bodies of the two articulating vertebrae except in the cervical region where it is partially deficient on either side. They are thicker in front in the cervical and lumbar regions for which the vertebral column presents the forward convexity in these regions. Throughout the vertebral column they are intimately adherent to the anterior and posterior longitudinal ligaments and in the thoracic region they give attachment to the radiate and the intra-articular ligaments. The intervertebral discs are elastic in nature and prevent shock between the vertebrae. They together form about one-fourth of the total length of the vertebral column.

THE ARTICULATIONS OF THE VERTEBRAL ARCHES

The vertebral arches of two contiguous vertebrae articulate with each other by their articular processes and form a plane type of synovial joint. The inferior articular processes of the vertebra above articulate with the superior articular processes of the vertebra below and they are connected together by capsular ligaments. Besides the capsular ligaments other accessory ligaments connect them together between their laminae, spines and the transverse processes. The following are the ligaments of the joint.

Capsular ligament.	Interspinous ligament.
Ligamenta flava.	Ligamentum nuchae.
Supraspinous ligament.	Intertransverse ligament.

Capsular ligament. It is a thin fibrous membrane which connects the articular processes of two contiguous vertebrae and is attached just beyond their articulating surfaces. It is lined internally by the synovial membrane. The capsular ligaments in the cervical region are comparatively looser than those of the other regions.

Ligamenta flava. The laminae of two adjacent vertebrae are connected to each other by the ligamenta flava. Superiorly, it is attached to the lower part of the anterior surface of the lamina above, and inferiorly, each is attached to the posterior surface and the upper margin of the lamina of the vertebra below. Anteriorly it is continuous with the capsular ligament while posteriorly each ligament reaches the median plane where it approaches its fellow of the opposite side. Structurally it consists of yellow elastic fibres. It is stretched during flexion of the vertebral column and recoils back during extension and thus adds a spring-action to the extending vertebral column.

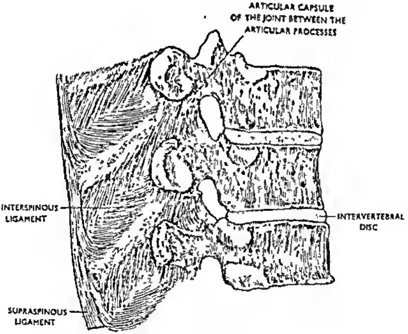


Fig. 444. The vertebral joints in the thoracic region. Seen from the right side.

Supraspinous ligament. It is a strong fibrous band which connects the tips the spinous processes from seventh cervical to the spinous process of the fourth

sacral vertebra. It can be divisible into three sets of fibres, the most superficial fibres connect three or four vertebrae together, the deepest fibres extend between two while the intermediate fibres extend over the spines of two or three vertebrae.

Interspinous ligament. It is a more membranous structure and each is confined between the spinous processes of two contiguous vertebrae. Anteriorly it blends with the ligamenta flava and posteriorly it fuses with the supraspinous ligament.

Ligamentum nuchae. It is present in the neck region only and replaces the supraspinous ligaments of the other regions. Above, it is attached to the external occipital protuberance, and below to the tip of the seventh cervical spine and forms a cord-like structure; between these two points it is attached to the external occipital crest, posterior tubercle of the first cervical vertebra and to the spines of all other cervical vertebrae as a thin lamina extending from the superficial thicker part. It forms a median partition between the muscles of the two sides of the neck. It contains elastic fibres and functions in the same way as the ligamenta flava. It is much well-developed in quadruped animals.

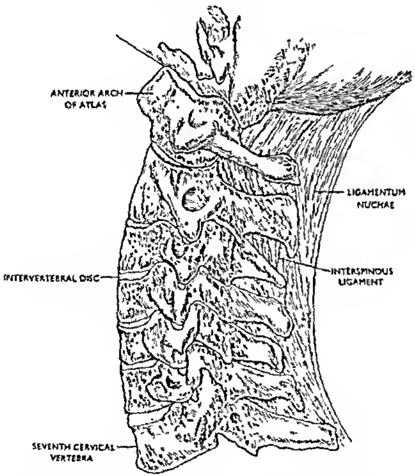


Fig. 445. The connections between the cervical vertebrae and between the atlas and the occipital bone. Seen from the left side.

Intertransverse ligament. Each ligament spreads between the tips of the transverse processes of two contiguous vertebrae. It is well developed in the thoracic region where it forms a cord-like structure. It is ill-defined in the cervical region and membranous in the lumbar region.

Movements of the vertebral joints. The movements of the vertebral joints are flexion, extension, lateral flexion, rotation and the circumduction.

The movement of flexion and extension are quite free in the cervical and the lumbar regions but it is restricted in the thoracic region because of the shortness and uniform thickness of the intervertebral discs in this region. The overlapping laminae in the thoracic region also prevent free flexion and extension.

The movement of lateral flexion is much limited in the thoracic region due to tension of the ligaments and the antagonist muscles. It is quite free in the cervical and lumbar regions.

Rotation to some degrees is permitted in these joints and in this the bodies of the vertebrae rotate on the intervertebral discs.

Circumduction is a combination of movements of flexion and extension which follow one after another in succession.

COSTO-VERTEBRAL ARTICULATIONS

The costo-vertebral articulation consists of two joints, one between the head with the body or the bodies of the two adjacent thoracic vertebrae and the other between the tubercle of the rib and the transverse process of the thoracic vertebra.

ARTICULATION OF THE HEADS OF THE RIBS. The first, tenth, eleventh and the twelfth ribs articulate with the corresponding vertebra by a single facet while the rest of the ribs articulate with the two adjacent vertebrae by two facets—upper and lower. The upper facet articulates with the vertebra above whereas the lower facet articulates with the corresponding vertebra. The ligaments of the joint are capsular, radiate and intra-articular.

The **capsular ligament** is very thin and surrounds the articular surfaces except anteriorly where its place is taken up by the radiate ligament. It is lined internally by a synovial membrane.

The **radiate ligament** is attached laterally to the anterior aspect of the head of the rib and as it passes medially it splits up into three bands—ascending, descending and transverse. The ascending band passes upwards to be attached to the body of the vertebra above, the descending band passes downwards to be attached to the vertebra below while the transverse band passes transversely to be attached to the intervertebral disc. In case of the first, tenth, eleventh and the twelfth ribs the transverse band is wanting. In case of the first rib the upper band is attached to the body of the seventh cervical vertebra.

The **intra-articular ligament** is placed within the joint and is a short band of fibres which connects the crest of the head of the rib with the intervertebral disc. It subdivides the joint cavity into two compartments—each being lined by a separate synovial membrane. The intra-articular ligament is wanting in case of the first, tenth, eleventh and the twelfth ribs.

Artery supply. This joint is supplied by branches from the posterior intercostal artery.

Nerve supply. It is supplied by branches from the intercostal nerve.

COSTO-TRANSVERSE JOINT. It is a synovial joint of the plane type. The bony parts entering into this articulation are the articular tubercle of the rib and the articular facet on the anterior aspect of the transverse process of the thoracic vertebra. The ligaments of the joint are the capsular, superior costo-transverse, costo-transverse and the lateral costo-transverse.

Capsular ligament. It is very thin and delicate and surrounds the articular surfaces and is lined internally by synovial membrane.

Superior costo-transverse ligament. Superiorly, it is attached to the lower border of the transverse process of the vertebra above, and inferiorly, it is attached to

the crest of the neck of the rib immediately below the transverse process. It consists of two sets of fibres which form two layers, anterior and posterior. The *anterior layer* is attached below to the crest of the neck of the rib and running upwards and laterally it is attached above to the lower border of the transverse process of the vertebra above. Laterally its fibres are continuous with the internal intercostal membrane. The *posterior layer* runs upwards and medially and is attached below to the area behind the crest of the neck of the rib and above to the lower border of the transverse process of the vertebra above.

Costo-transverse ligament. It connects the posterior aspect of the neck of the rib with the anterior aspect of the corresponding transverse process. It is rudimentary in case of the eleventh and the twelfth ribs.

Lateral costo-transverse ligament. It is a thick, strong ligament which connects the non-articular part of the tubercle of the rib to the lateral end of the transverse process.

Artery supply. It is supplied by branches from the posterior intercostal arteries.

Nerve supply. It is supplied by the intercostal nerve.

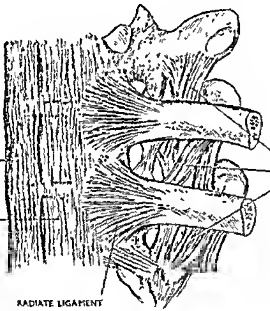


Fig. 446. The costo-vertebral joints. Seen from the left side.

STERNO-COSTAL JOINTS. Each sterno-costal joint consists of the articular notch of the sternum and the sternal end of the costal cartilage. Except the first sterno-costal articulation which is a primary cartilaginous joint all the other sterno-costal joints are of synovial type. The ligaments of the joint are capsular and radiate sterno-costal, intra-articular and costoxiphoid.

Capsular ligament. It is very thin and surrounds the articular surfaces. It is intimately connected with the sterno-costal ligament.

Radiate sterno-costal ligament. It connects the anterior and posterior aspects of the sternal end of the cartilage with the corresponding aspects of the sternum. It is triangulr in shape, the apex of which is attached to the costal cartilage while its base divides into ascending, descending and transverse bands. The ascending band intermingles with the fibres of the ligament above and the descending band with the ligament below while the transverse band intermingles with the fibres of the fellow

of its opposite side. These bands also intermingle with the tendinous fibres of origin of the pectoralis major and together they form a membrane which envelopes the bone.

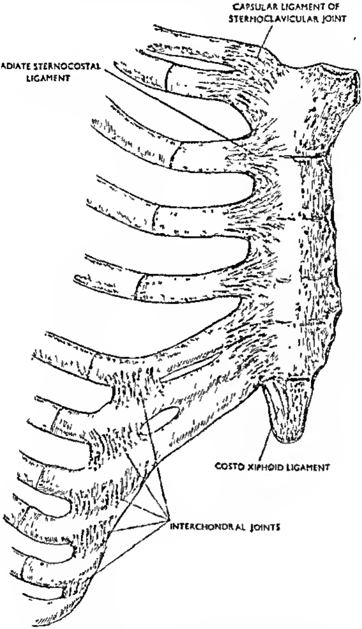


Fig. 417. The sterno-clavicular, the sterno-costal, inter-chondral and the xiphisternal joints Seen from the front.

Intra-articular ligament. This ligament is usually present in the second joint and may be present in some of the succeeding joints. In the second joint, laterally, it is attached to the sternal end of the costal cartilage and medially, to the fibrocartilage between the manubrium sterni and the body. It subdivides the joint cavity into two compartments, each having a separate synovial lining.

Costo-xiphoid ligament. It connects the anterior and posterior aspects of the seventh costal cartilage with the corresponding aspect of the xiphoid process.

INTERCHONDRAL JOINTS. These are synovial joints of the plane type and are present opposite the contiguous borders of sixth and seventh, seventh and eighth, eighth and ninth costal cartilages. Each joint is surrounded by a capsular ligament which is lined internally by a synovial membrane.

Movements of the thorax. The principal movement of the thorax is the *movement of respiration* which is a two-phase movement consisting of *inspiration* and *expiration.*

In the infants, from birth upto the end of first year, the costo-chondral arches are roughly horizontal and therefore, they do not provide any leverage for expansion of the thoracic cage either transversely or anteroposteriorly; the diaphragm muscle moves up and down like a piston causing decrease and increase in the vertical diameter of the thorax respectively and thus the respiratory movement at this age is of *abdominal type.* By the second year the ribs become oblique and the obliquity becomes well developed by seventh year since when the movement of respiration is performed mostly by the ribs and is known as the *thoracic type of respiration* in which all the three diameters of the thorax are increased during inspiration.

The inspiratory movement is an active movement brought about by the synchronised actions of many muscles whereas the expiratory movement is mostly a passive one brought about by the elastic recoil of the lungs and by relaxation of the muscles of inspiration. With little alteration the mechanism remains the same both in quiet inspiration as well as in deep and forced inspirations.

Mechanism of quiet inspirations. *Increase of the transverse and anteroposterior diameters.* The first thoracic vertebra together with the first two ribs and the manubrium sterni forms a fixed ring which allows other ribs to move towards it. The intercostals rotate the *2nd—7th* costal arches at their costo-vertebral joints, and as a result, their middle parts rise above and their lower borders become everted and this causes an increase in the transverse diameter of the thorax. The *8th, 9th*, and the *10th* ribs do not work in the same way as the upper ribs. These ribs cannot rotate because of the antero-superior positions of the costal facets on the transverse processes but they glide upwards and backwards and thereby increasing the transverse diameter of the lower thorax. Concurrently the intercostals raise the anterior ends of the costo-chondral arches and as a result the sternum (body) is pushed forwards causing an increase in the anteroposterior diameter of the thorax. The costo-chondral arches being larger from above downwards the lower sternum (lower part of body) takes a greater excursion in the forward thrust than the upper sternum which makes a hinge-like movement at the sterno-manubrial joint with minimum forward thrust.

Increase in the vertical diameter. The increase in the vertical diameter of the thorax is brought about by the descent of the diaphragm muscle. The quadratus lumborum muscles of the two sides fix the twelfth ribs by their contraction and the fibres of origin of diaphragm from the vertebral bodies and the lumbocostal arches contract causing widening of the costo-diaphragmatic space and descent of the domes of the diaphragm and thus increases the vertical diameter of the thorax. With the descent of the diaphragm the upper abdominal viscera also descend causing the forward thrust of the anterior abdominal wall.

Mechanism in deep and forced inspirations. There is not much difference in deep and forced inspirations from the mechanism in quiet inspiration except that the movements are exaggerated in the former two conditions.

In *deep inspiration* the usual mechanism in quiet inspiration is repeated and on the top of this some additional forces come into play as follows. The first and the second costal arches are raised by the scalenei and the manubrium sterni is also raised by the sternal head of sternocleidomastoid; the levatores costarum and serratus posterior superior also assist in raising the upper ribs.

In *forced inspiration* some other additional forces come into play to help the inspiratory effort. The point of the shoulder is raised and the scapula is fixed by

trapezius, levator scapulae and the rhomboidei (the same condition may be achieved by holding the handle of chair or some other object) and the pectoralis minor draw the upper ribs upwards making more room for the lungs to expand; the erector spinae also contract to straighten the dorsal vertebral column so that the ribs might have better leverage to work.

The movement of expiration. This movement is mostly a passive one and is brought about by the elastic recoil of the lungs, by relaxation of the muscles of inspiration thereby allowing the ribs regaining their normal position of rest. In forced expiration the flat muscles of the abdomen contract so as to increase the intra-abdominal pressure which makes an upward thrust on the diaphragm which in turn produces a squeezing action over the lungs.

ATLANTO-OCCIPITAL JOINTS

The "atlanto-occipital joints" as the name implies are the joints formed between the atlas and the occipital condyles. They form two joints, one on each side and the bony parts entering into the articulation are the occipital condyles and the superior articular facets of the atlas. Each joint is a *condyloid type of synovial joint* and its long axis is obliquely set being directed from behind forwards and medially and the two joints work simultaneously as one joint. The ligaments of the joints are as follows:

(1) Two capsular ligaments—one on each side.
(2) Anterior atlanto-occipital membrane.
(3) Posterior atlanto-occipital membrane.

(1) **Capsular ligament.** It is attached above to the margins of the occipital condyle and below to the margins of the superior articular facet of the atlas. The ligament is comparatively thin and is of loose texture and is lined internally by synovial membrane. Anteriorly it fuses with the anterior antlanto-occipital membrane and posteriorly with the posterior atlanto-occipital membrane.

(2) **Anterior atlanto-occipital membrane.** It is a broad membranous sheet which bridges across the gap between the upper border of the anterior arch of the atlas and the anterior margin of the foramen magnum. Above it is attached to the anterior margin of the foramen magnum and below to the upper border of the anterior arch of the atlas. Opposite the median plane it is thicker being reinforced by the fibres of the anterior longitudinal ligament while at the periphery it is thinner; on each side its lateral margin becomes fused with the capsular ligament of the atlanto-occipital joint.

(3) **Posterior atlanto-occipital membrane.** It is attached above to the posterior margin of the foramen magnum, and below, to the posterior arch of the atlas. On the latter it bridges over the groove on the posterior arch of the atlas and converts it into a foramen through which the suboccipital nerve and the vertebral artery pass. It is comparatively thinner than the anterior atlanto-occipital membrane and anteriorly, on either side, it fuses with the capular ligament of the atlanto-occipital joint. The margin of the ligament which bridges over the groove for the suboccipital nerve and the vertebral artery, may sometimes be ossified.

Movements of the joints. The two joints work simultaneously as one joint and the movement takes place around two axes namely, transverse and antero-posterior. The movements in the transverse axis are *flexion* and *extension* or the nodding movement of the head as we answer something in the affirmative.

Oblique lateral movement. In this the movement occurs in a ventro-dorsal axis, as in turning the head sidewards. In this movement the anterior end of one of the occipital condyles glides forwards and medially towards the median plane while the other recedes backwards and laterally. Muscles concerned are the

otators of the atlanto-xial joint.

The muscles concerned in each of the other movements are as follows:

Flexion. Rectus capitis anterior and longus capitis.

Extension. Trapezius, semispinalis capatis, rectus capitis posterior major et minor, obliquus capitis superior and splenius capitis.

Lateral flexion. Sternocleidomastoid, trapezius, rectus capitis lateralis, splenius capitis and semispinalis capitis.

Artery supply. It is supplied by branches from the vertebral artery or from the meningeal branches of the ascending pharyngeal artery.

Nerve supply. The joints are supplied by twigs from the suboccipital nerve.

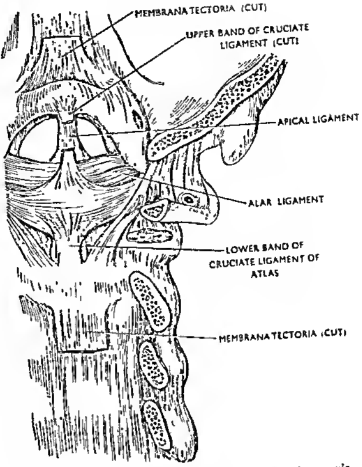


Fig. 448. The atlanto-occipital and the atlanto-axia joints. Opened up from behind

ATLANTO-AXIAL JOINTS

The axis or the second cervical vertebra articulates with the atlas by three joints, two lateral and one median. All the three joints are of synovial type of which, the median one is a pivot joint while the lateral ones are of plane type of synovial joint.

THE MEDIAN ATLANTO-AXIAL JOINT. The median atlanto-axial joint is formed between the odontoid process of the axis, and the transverse ligament of the atlas and the facet on the back of the anterior arch of the atlas. It is a pivot type of synovial joint and there are two separate small joint cavities—one between the back of the odontoid process and the transverse ligament of the atlas and the other between the odontoid process and the back of the anterior arch of the atlas. Each joint cavity is surrounded by a small thin capsule lined internally by a synovial membrane.

LATERAL ATLANTO-AXIAL JOINTS. The two superior articular facets of the axis, one on each side, articulate with the corresponding inferior articular facets of the atlas and form the lateral atlanto-axial joints. Although it is a plane joint, each of the superior articular facets of the axis is gently convex and is obliquely placed being inclined downwards and laterally and the corresponding inferior articular facet of the atlas is reciprocally concave to form a close fitting. A thin capsular ligament surrounds each joint which is lined internally by a synovial membrane. In addition to the capsular ligaments the following are the other ligaments of the atlanto-axial joints.

(1) Transverse ligament of the atlas.
(2) Accessory atlanto-axial ligament.
(3) Atlanto-axial membrane.
(4) Ligamentum flavum (between atlas and axis).
(5) Occipito-axial ligaments:
  (a) Apical ligament.
  (b) Cruciate ligament (upper and lower ends).
  (c) Membrana tectoria.
  (d) Alar ligaments.

(1) **Transverse ligament of the atlas.** It is a thick stout ligament that stretches transversely across the back of odontoid process of the axis and is attached on either side to the tubercle on the medial side of the lateral mass of the atlas. Opposite the median plane it is joined from both above and below by a narrower band and presents an appearance of a St. Andrews cross for which the transverse ligament together with its upper and lower bands is known as the *cruciate ligament of the atlas*. The upper band of the cruciate ligament is attached above to the inner surface of the basilar part of the occipital bone below the membrane tectoria and between it and the apical ligament. The lower band of the cruciate ligament is attached below to the lower part of the back of the body of the axis.

(2) **Accessory atlanto-axial ligament.** It is a short oblique band which is attached above to the posterior part of the lateral mass of the atlas and descending downwards and medially postero-medial to the back of the atlanto-axial joint it is attached below to the back of the lower part of the body of the axis.

(3) **Atlanto-axial membrane.** The anterior longitudinal ligament in its course downwards from the tubercle on the anterior arch of the atlas gives sideward expansion which bridges across the gap between the lower part of the anterior arch of the atlas and the axis and forms the atlanto-axial membrane. It is attached above to the lower border of the anterior arch of the atlas and below to the body of the axis

(4) **The ligamentum flavum.** This ligament bridges across the gap between the lower part of the posterior arch of the atlas and the vertebral arch of the axis and forms the highest ligamentum flavum. It is pierced by the second cervical nerve.

(5) Occipito-axial ligaments:

(a) **Apical ligament.** It is a narrow vertical band which is attached above to the basilar part of the occipital bone below the superior band of the cruciate ligament and between it and the anterior atlanto-occipital membrane; below it is attached to the apex of the odontoid process.

(b) **Cruciate ligament** has already been described.

(c) **Membrana tectoria.** It is a broad membranous sheet which ascends upwards as a direct continuation of the posterior longitudinal ligament and is attached above to the upper surface of the basilar part of the occipital bone between the anterior condylar canals. In its course upwards it covers the accessory atlanto-axial ligament, the odontoid process, the apical, the cruciate and the alar ligaments. Because it covers the above structures it is called "membrana tectoria".

(d) **Alar ligaments.** The alar ligaments are two oblique thick bands, one on each side of the odontoid process, which connect the odontoid process with the occipital condyles. Each alar ligament is attached below to the side of the odontoid process below its apex, and ascending upwards and laterally it is attached to the medial aspect of the occipital condyle.

Artery supply. The arteries supplying the joints are derived from the vertebral arteries.

Nerve supply. The nerves supplying the joints are derived from the loop between the first and the second cervical nerves.

Movements. The principal movement in these joints is *rotation* which takes place around a vertical axis with the odontoid process as the pivot. The muscles concerned in this movement are the following:

Left rotation—
Right trapezius
,, sternomastoid
,, splenius, longissimus and longus capitis
,, obliquus capitis inferior
,, rectus capitis posterior major

Right rotation—
Corresponding muscles of the opposite sides

THE TEMPORO-MANDIBULAR JOINT

The temporo-mandibular joint is a diarthrodial joint of the ginglymus type. Cunningham). The bony parts entering into the articulation are the articular 'minence and the anterior portions of the mandibular fossa of the temporal bone ıbove, and the head of the mandible below with the articular disc intervening ıetween them.

Articular disc. It is an oval plate-like fibro-cartilaginous disc which covers he articular surfaces of the mandibular joint and its circumferential margin gives ıttachment to the capsular ligament of the joint. The articular disc completely livides the joint cavity into two distinct compartments which are completely eparated from each other. This division of the joint cavity into two compartments s a peculiar feature of this joint which distinguishes it from the other members of the synovial joints. The upper surface of the articular disc is concavo-convex so as to adapt it to the shape of the articular fossa and the articular eminence of the emporal bone. Its lower or inferior surface is concave so as to fit with the convex ıead of the mandible. Each compartment of the joint cavity, upper and lower, is separately lined with synovial membrane.

Anteriorly the disc gives attachment to the tendon of the lateral pterygoid nuscle through the capsular ligament. The disc represents the compressed tendon of lateral pterygoid muscle which, in embryonic life, passed between the head of the nandible and the articular fossa and was inserted into the malleus.

Ligaments of the joint—
(1) Capsular ligament.
(2) Temporo-mandibular ligament.
(3) Stylo-mandibular ligament.
(4) Spheno-mandibular ligament.

(1) **Capsular ligament.** It is loose and thin and completely surrounds the joint. Above it is attached to the articular eminence in front, and the margins of the squamo-tympanic fissure behind, and between these two points, to the circumference of the articular fossa.

Below it is attached to the neck of the mandible. Between its upper and lower attachments it is attached to the circumference of the articular disc.

(2) **Temporo-mandibular ligament.** It is a strong triangular band of fibres lying in close contact with the capsular ligament on its lateral side. It is attached above, by its broad base, to the lateral surface of the zygomatic process of the temporal bone and to the tubercle at the root of the zygomatic process. Below it is attached to the lateral surface and posterior border of the neck of the mandible.

(3) **Stylo-mandibular ligament.** It is a specialised band of deep cervical fascia and is derived from that portion of the deep cervical fascia which forms a part of the capsule of the parotid gland. Above it is attached to the lateral aspect

of the styloid process of the temporal bone and below it is attached to the angle of the mandible between the medial pterygoid and the masseter muscles.

(4) **Spheno-mandibular ligament.** It is a long membranous band of fibres which lies on the medial side of the joint and is attached above to the spine of the sphenoid bone and below to the lingula of the mandible. It is separated from the capsular ligament by a considerable distance. It is the remnant of the sheath of

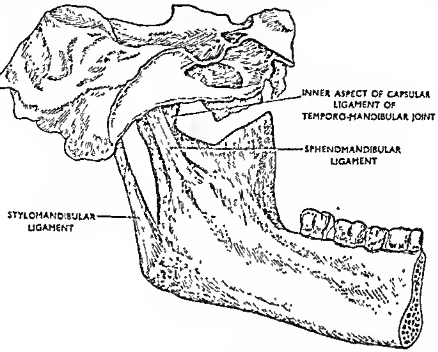


Fig. 449. The left temporo-mandibular joint seen from the medial side.

the Meckel's cartilage and its upper attachment to the sphenoidal spine is a secondary attachment. Its primary attachment may be traced to the anterior process of malleus through the medial end of the petrotympanic fissure.

Superiorly, its lateral surface is related to the lateral pterygoid muscle and the auriculotemporal nerve, and lower down, it is separated from the neck of the mandible by the maxillary vessels, and still lower down, intervening between it and the ramus of the mandible, are the inferior dental vessels and nerve and a portion of the parotid gland. Medially and below it is related to the medial pterygoid muscle while medially and above it is crossed by the chorda tympani nerve (at its extreme upper end) and is separated from the pharynx by an interval which contains some fat and the pharyngeal venous plexus. Close to its lower end it is pierced by the vessels and nerve to the mylohoid muscle.

N.B. The capsular and the temporo-mandibular ligaments are the true ligaments of the joint as they are directly supporting the articulation. The spheno-mandibular and the stylo-mandibular ligaments are placed at a considerable distance from the capsular ligament and they are not playing any important role in the support of the joint and hence they are called by some authors as accessory ligaments.

Synovial membrane. It lines the inner surface of the capsular ligament in each compartment of the joint cavity; inferiorly it is reflected upwards on to the neck of the mandible from the inner surface of the capsular ligament. The two joint cavities are completely separated from each other by the articular disc.

Movements of the joint. The movements of the temporo-mandibular joint are depression, elevation, protrusion, retraction and grinding or side-to-side

movement. In all these movements the joints of both the sides work together as a single unit.

(1) *Depression.* In this movement the lower jaw is depressed, as in opening the mouth, the angle of the mandible is drawn backwards and the head of the mandible moves forwards. The movement takes place in both the compartments of the joint; in the lower compartment the head of the mandible takes a hinge-movement whereas in the upper compartment the head of the mandible together

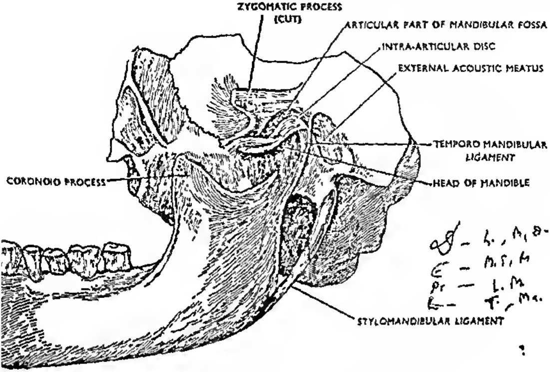


Fig. 450. The left temporo-mandibular joint seen from the outer aspect.

with the articular disc takes a gliding-movement forwards. In the initial phase the hinge-movement operates whereas during the later phase the gliding-movement operates in which the head of the mandible together with the articular disc rolls downwards and forwards over the articular eminence.

The muscles concerned in this movement are digastric, mylohyoid, geniohyoid and lateral pterygoid.

(2) *Elevation.* This is a reverse movement of the above in which the mouth is closed from the opened-up position.

The muscles concerned are the masseter, temporalis and the anterior fibres of the medial pterygoid.

(3) *Protrusion.* In this movement the lower jaw projects forwards beyond the upper incisors, the movement taking place in the upper joint cavity.

The muscles concerned are the medial and lateral pterygoids.

(4) *Retraction.* This is the reverse movement of protrusion and the muscles concerned in this movement are the masseter and the temporalis.

(5) *Grinding or Side-to-side movement.* This is a chewing movement in which the chin is displaced to one side or the other and then comes back to occlusal position. In this the head of the mandible of one side together with the disc glides forwards —movement taking place in the upper joint cavity—and then it rotates on the disc —movement taking place in the lower joint cavity around a vertical axis passing behind the head of the opposite side. Then a reverse movement takes place to bring back the lower jaw in occlusal position. The lateral and the medial pterygoid muscles work alternately to cause this movement.

Artery supply. Arteries supplying the joint are the superficial temporal and the maxillary branches of the external carotid artery.

Nerve supply. Nerves are the articular branches from the auriculotemporal and masseteric branches of the mandibular nerve.

THE ARTICULATIONS OF THE SUPERIOR EXTREMITY

THE STERNO-CLAVICULAR JOINT

The *sterno-clavicular articulation* is a plane synovial joint in which the joint cavity is divided into two compartments by an articular disc. The parts entering into the articulation are the clavicular notch of the sternum, the sternal end of the clavicle and the sternal end of the first costal cartilage. The articular disc is interposed between the two articular surfaces and is attached superiorly to the upper margin of the clavicle and inferiorly to the first costal cartilage.

Ligaments of the joint—

(1) Capsular ligament.
(2) Anterior sterno-clavicular ligament.
(3) Posterior sterno-clavicular ligament.
(4) Interclavicular ligament.
(5) Costo-clavicular ligament.

Capsular ligament. It is thin and weak and surrounds the margins of the articular surfaces. It is also attached to the peripheral margins of the articular disc. Thus the joint cavity is divided into two compartments, each being lined separately by the synovial membrane.

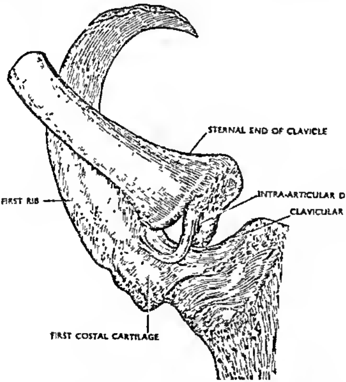


Fig. 451. The interior of the left sterno-clavicular joint to show the attachments of the intra-articular disc.

Anterior sternoclavicular ligament. It strengthens the capsular ligament anteriorly and extends from the anterior margin of the sternal end of the clavicle to the anterior margin of the clavicular notch of the sternum.

Posterior sternoclavicular ligament. It strengthens the posterior part of the capsular ligament and connects the posterior margin of the sternal end of the clavicle with the posterior margin of the clavicular notch of the sternum.

Interclavicular ligament. It is a thickened band placed on the superior aspect of the capsular ligament and extends from one clavicle to the other along the upper border of the manubrium sterni to which its fibres are also attached.

Costo-clavicular ligament. It is placed on the inferior aspect of the clavicle and extends from the upper surface of the first costal cartilage to the costal impression on the inferior surface of the clavicle just lateral to the joint. It consists of two laminae, anterior and posterior, which are usually separated from each other by a bursa. The *anterior lamina* ascends upwards and laterally from the first costal cartilage and is attached to the anterior margin of the costal impression of the clavicle. The *posterior lamina* ascends upwards and medially and is attached to the posterior margin of the costal impression of the clavicle.

Relation of the joint. Anteriorly it is in relation to the sternal head of the sternomastoid muscle. Posteriorly it is related to the sternohyoid and sternothyroid muscles which separate it from the vagus nerve and the great vessels at the root of the neck.

Nerve supply. It is supplied by the medial branch of the supraclavicular nerve and by a branch from the nerve to the subclavius.

Artery supply. Arteries are derived from the internal mammary branch of the subclavian artery and from the suprascapular artery.

Movements. Four movements, elevation, depression, forward and backward movements, are permitted in this joint and they accompany the movement of the shoulder girdle.

THE ACROMIOCLAVICULAR JOINT

The acromioclavicular joint is a *plane type of synovial joint* formed between the acromial end of the clavicle and the medial aspect of acromion process of the scapula. The articular facet on the acromial end of the clavicle is covered by fibrocartilage,

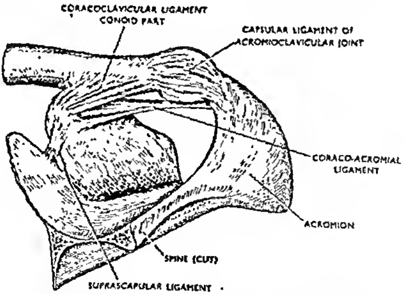


Fig. 452. The right acromio-clavicular joint and the coraco-clavicular connections. Seen from behind.

is oval in form and is directed downwards and laterally whereas the clavicular articular facet of the acromion is similar in form and is directed medially and slightly upwards.

The ligaments of the joint are the following :

Capsular ligament.
Acromioclavicular ligament.
Coracoclavicular ligament
(*a*) Conoid part.
(*b*) Trapezoid part.

Capsular ligament. It forms a fibrous cuff between the bony parts entering into the articulation and is attached to them just beyond their articular surfaces. It is lined internally by synovial membrane. Occasionally an articular disc may be present which divides the joint cavity either completely or incompletely.

Acromioclavicular ligament. It connects the superior aspect of the acromial end of the clavicle with the adjoining part of the acromion and forms a quadrilateral band which strengthens the capsular ligament superiorly. It consists of parallel fibres some of which interlace with the tendinous fibres of insertion of the trapezius posteriorly and with the similar fibres of origin of the deltoid anteriorly.

Coracoclavicular ligament. It is a strong ligament which connects the acromial end of the clavicle with the coracoid process of the scapula. It consists of two parts, *conoid* and *trapezoid*, being separated from each other by a bursa.

The *conoid part* lies postcromedial to the trapezoid part and forms a triangular dense fibrous band. It is attached to the medial and posterior edge of the root of the coracoid process in front of the scapular notch by its apex while its base is attached to the conoid tubercle and to the adjoining area medial to it on the under-surface of the clavicle at the junction between its medial three-fourths and lateral one-fourth posteriorly.

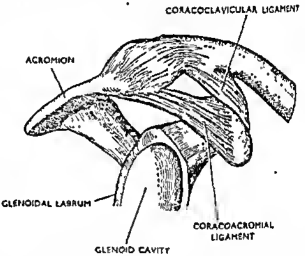


Fig. 453. The right acromio-clavicular joint and the coraco-clavicular connections. Seen from the front.

The *trapezoid part* of the coracoclavicular ligament forms a quadrilateral band of fibres which is attached below to the upper surface of the horizontal part of the coracoid process, the attachments extending behind to the root of the coracoid process; superiorly it is attached to the trapezoid ridge on the under-surface of the lateral one-fourth of the clavicle. Its posterior border fuses with the conoid part while its anterior border forms a free margin.

Artery Supply. The joint is supplied by branches from suprascapular and thoraco-acromial arteries.

Nerve supply. It is supplied by branches from the suprascapular and lateral pectoral nerves.

THE INTRINSIC LIGAMENTS OF THE SCAPULA

The intrinsic ligaments of the scapula are the transverse scapular (suprascapular), the coraco-acromial and the spinoglenoid ligaments.

Transverse scapular ligament. It is a thin short band of fibres that bridges across the scapular notch and converts the latter into a foramen. It is attached medially to the medial end of the scapular notch and laterally to the root of the coracoid process. It is usually wider at its extremities but narrower in its centre

and may occasionally be ossified. The suprascapular vessels cross over the ligament whereas the suprascapular nerve passes through the foramen.

Coraco-acromial ligament. It forms a strong triangular band which stretches between the coracoid and the acromion processes of the scapula and together with the under surface of the acromion forms the *coraco-acromial arch*. Its apex is attached to the tip of the acromion just in front of the clavicular facet; its base is attached to the lateral margin of the horizontal part of the coracoid process.

Spinoglenoid ligament. It forms a thin membranous band that connects the lateral border of the spine of the scapula to the adjoining margin of the glenoid cavity. It is a inconstant band which, when present, bridges over the suprascapular vessels and nerve in their course to the infraspinous fossa.

THE SHOULDER JOINT

The shoulder joint belongs to the ball and socket sub-group of the diarthrodial joint. It is the most movable of all the joints. The bony parts entering into the articulation are the glenoid cavity of the scapula and the head of the humerus. The glenoid cavity of the scapula forms a shallow socket which is smaller than the large head of the humerus and when the two bones articulate, only a portion

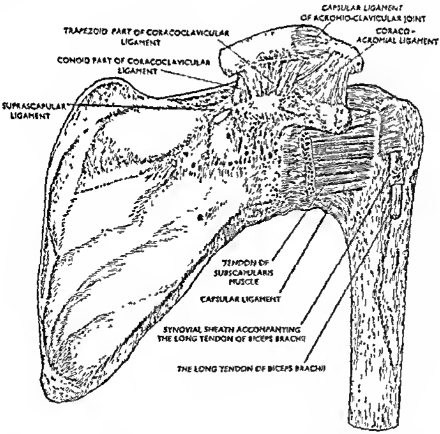


Fig. 454. The left shoulder joint and the acromio-clavicular joint. Seen from the front.

of the head comes into contact with the glenoid cavity and the rest of the head extends beyond the circumferential margin of the glenoid cavity and consequently, during active movements of the joint, the head is not to meet any bony resistance.

Ligaments of the joint—

(1) *Capsular ligament.*

(a) Coraco-humeral ligament.

(b) Superior gleno-humeral ligament.
(c) Middle gleno-humeral ligament.
(d) Inferior gleno-humeral ligament.
(2) *Transverse humeral ligament.*
(3) *Glenoidal Labrum.*

Capsular ligament. The capsular ligament of the shoulder joint extends from the margins of the glenoid cavity to the anatomical neck of the humerus and ensheathes the bony parts entering into the articulation. It is strengthened by four supplemental bands, the coracohumeral and the three gleno-humeral ligaments, which are nothing but localised thickening of the capsular ligament and cannot be separated from it without injuring the latter.

The capsular ligament consists of an outer fibrous and an inner synovial stratum. The fibrous stratum is fairly dense and strong and envelopes the articulation from all sides. The synovial membrane lines the interior of the fibrous stratum and forms several bursal protrusions through the openings in the capsular ligament.

It also invaginates the long tendon of the biceps brachii as it passes between it and the capsular ligament. Thus the long tendon of the biceps brachii is intracapsular but is extrasynovial and lies outside the joint cavity.

Attachments of the capsular ligament. *Medially* it is attached to the scapula around the margins of the glenoid cavity except superiorly where the line of attachment extends as far as the root of the coracoid ~~process~~ and encloses the origin of the long tendon of the biceps brachii within its attachment. Except superiorly it is blended with the glenoidal labrum.

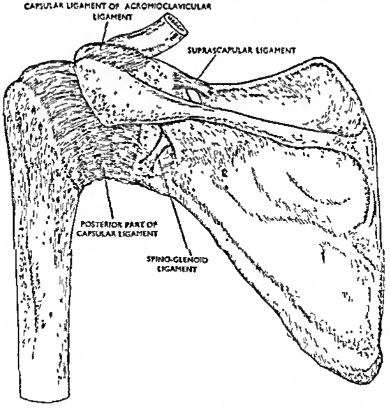


Fig. 455. The left shoulder joint. Seen from behind.

Laterally, it is attached to the anatomical neck of the humerus except inferomedially where it extends downwards for about one inch below the anatomical and thus enclosing the medial part of the surgical neck within its attachment.

Superiorly opposite the intertubercular sulcus it is not attached to the bone but it is attached to the transverse humeral ligament.

Openings in the capsular ligament. There are usually three openings in the capsular ligament—one anteriorly close to the root of the coracoid process and the synovial protrusion through it forms the *subscapular bursa*, one posteriorly and the synovial protrusion through it forms the *bursa for the infraspinatus* and the third one is present opposite the top of the intertubercular sulcus through which passes the long tendon of the biceps together with its synovial sheath.

Supplemental bands of the capsular ligament—coracohumeral ligament. It is a broad localised thickening on the external aspect of the capsule and is placed superiorly. It is attached, proximally, to the root and the lateral border of the coracoid process and distally, it is attached to the two tubercles and the transverse humeral ligament.

The gleno-humeral ligaments. They are the three localised thinkenings on the inner aspects of the capsular ligament and according to their situations they are named superior, middle and inferior gleno-humeral ligaments. They are all attached above to the upper, medial margin of the glenoid cavity being blended with the glenoidal labrum. The *superior band* lies on the medial side of the long tendon of biceps brachii and is attached below to the depression above the lesser tubercle of the humerus and it is considered to be homologous with the ligament of the head of the femur. The *middle band* is attached below to the humerus in front of the lesser tubersity. The opening for the subscapular bursa intervenes between the superior and the middle bands. The *inferior band* is attached below to the lower part of the anatomical neck of the humerus.

Relations of the capsular ligament. Superiorly it is covered by the supraspinatus which is closely applied on it; *anteriorly* by the subscapularis and *posteriorly* by the infraspinatus and the teres minor; inferiorly it is related to the long head of the triceps brachii but is separated from it by the intervening posterior circumflex humeral vessels and the axillary (circumflex) nerve.

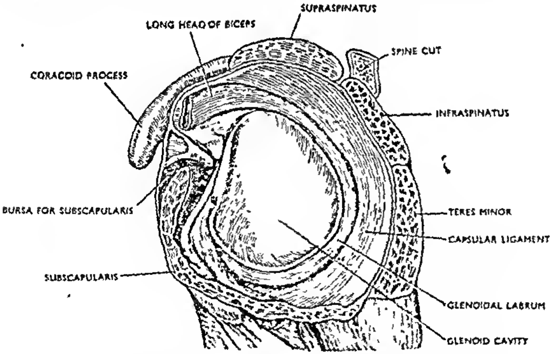


Fig. 456. A section through the shoulder joint to show its interior on the scapular side.

Vessels and nerves supplying the capsular ligament. The arteries supplying the capsular ligament are the suprascapular and the anterior and posterior circumflex humeral arteries.

The **nerves** supplying the capsular ligament are the suprascapular and the axillary (circumflex) nerves.

N.B. The capsular ligament of the shoulder joint is exceedingly lax, so much so, that by traction, the glenoid cavity and the head of the humerus can be separated from each other by a considerable gap and due to this laxity it is so often dislocated. On all sides the capsular ligament is guarded by strong muscles except inferomedially where there is a gap between the capsular ligament and the long head of the triceps and it is through this part that the head of the humerus makes a rent in the capsular ligament during dislocation.

Transverse humeral ligament. It is a broad fibrous band that bridges across the intertubercular sulcus and is attached to the lesser tubercle in front and to the greater tubercle behind. It converts the intertubercular sulcus into a canal through which the long tendon of the biceps brachii together with its synovial sheath and the ascending branch of the anterior circumflex humeral artery pass.

Glenoidal labrum. It is a dense fibro-cartilaginous rim which surrounds the glenoid cavity and is attached to its rim-like margin. At its periphery it is fused with the capsular ligament, and by its attachment it deepens the glenoid cavity.

Bursa around the shoulder joint. (1) Subscapular bursa intervenes between the tendon of the subscapularis muscle and the scapula and communicates with the joint.

(2) Bursa for the infraspinatus muscle is the synovial protrusion through the opening in the posterolateral part of the capsular ligament and communicates with the joint cavity.

(3) Sub-acromial bursa is situated at the summit of capsular ligament and intervenes between it and the deltoid.

(4) Bursa for the long tendon of the biceps brachii lies in the floor of the bicipital groove and communicates with the joint cavity.

(5) Sub-deltoid bursa intervenes between the insertions of the deltoid and the humerus.

(6) One is present below the tip of the acromion process.

(7) One is placed between the coracoid process and the capsule.

(8) One is placed in front of and another behind the tendon of insertion of the latissimus dorsi.

(9) One is situated between the teres major and the long head of the triceps.

Movements in the shoulder joint. The shoulder joint being a ball and a socket joint all sorts of movements are permitted in this joint around an infinite number of axes that pass through the centre of the head of the humerus. However, for practical purposes three axes, *transverse*, *antero-posterior* and *vertical*, are usually considered around which most of the movements of the joint take place. The usual movements of the joint are flexion and extension, abduction and adduction, circumduction and rotation.

The movement of flexion and extension takes place around a transverse axis; the glenoid cavity being directed forwards and laterally the transverse axis does not run parallel to the coronal plane of the body and instead it meets the latter obliquely at an angle.

The movement of abduction and adduction takes place around an antero-posterior axis; due to the glenoid cavity being directed forwards and laterally this axis is also not strictly anteroposterior but it is obliquely set with the sigittal plane of the body.

The movement of rotation takes place around a vertical axis that passes through the centre of the head of the humerus and centre of the capitulum.

(a) *Flexion or forward movement.* In this the arm is carried forwards and medially. Muscles concerned are the anterior part of the deltoid, pectoralis major and ...hialis.

(*b*) *Extension or backward movement.* In this the arm is carried backwards and laterally. Muscles concerned are the latissimus dorsi, posterior part of the deltoid and the teres major.

(*c*) *Adduction.* In this movement the arm is carried forwards and medially, as in touching the opposite shoulder. The prime movers in this movement are the pectoralis major and the latissimus dorsi; and the teres major, anterior part of the deltoid, coracobrachialis, long head of the triceps and the biceps are the synergists.

(*d*) *Abduction.* In this movement the arm is carried away from the trunk making a right angle with the trunk. The deltoid and the supraspinatus are the true abductors of the shoulder joint and they work together.

The further movement of the arm above the shoulder is not a movement of the shoulder joint alone but it is associated with the movement of the shoulder girdle.

Deltoid fixes the head of the humerus against the glenoid cavity, the trapezius fixes the scapula on the back and the serratus anterior rotates the scapula laterally and a movement takes place in the sterno-clavicular articulation enabling the arm to be raised above the shoulder.

(*e*) *Circumduction.* This is a combination of all the movements which follow one after another in rapid succession in such a way that the head of the humerus taking a fixed point in the glenoid cavity rotates round it.

(*f*) *Medial rotation.* Muscles concerned in this are the pectoralis major, latissimus dorsi, teres major, deltoid and subscapularis.

(*g*) *Lateral rotation.* Muscles concerned in this movement are the infraspinatus, teres minor and the deltoid (post. fibres).

Inman, Dec. M. Saunders and Abbot have analysed the movement of elevation of the arm in abduction or in flexion in a critical way and they have divided the whole movement into three phases as follows :

Phase I

Elevation upto 60 degrees in flexion or 30 degrees in abduction

In addition to the principal movement at the glenohumeral joint the following accessory movements take place :

(*i*) Elevation of the acromial end of the clavicle by about 12-15 degrees.
(*ii*) The scapula rotates through an antero-posterior axis in one way or the other in most cases; it is less significant because it lacks in regularity for which it has been termed "the setting phase of the scapula".
(*iii*) The angle between the scapular spine and the clavicle is widened by 10 degrees and this is produced by the rotation of the scapula around a vertical axis through the acromioclavicular joint.
(*iv*) Rotation of the clavicle in its long axis does not occur in this phase.

Phase II

Elevation from the end of the phase I to 90 degrees of flexion or abduction

In addition to the movement at the gleno-humeral joint (shoulder joint) the following movements also take place:

(*i*) Further elevation of the acromial end of the clavicle to its final position at 30—36 degrees over its usual bearing with the mid-sagittal plane.
(*ii*) Spino-clavicular angle does not show any further change.
(*iii*) Rotation of the scapula in an antero-posterior axis takes place in 1 : 2 ratio with the movements at the glenohumeral joint, that is, for each 10 degrees of glenohumeral movement 5 degrees of scapular rotation take place.
(*iv*) Rotation of the clavicle in its long axis does not occur.

Phase III

Elevation vertically overhead from the end of Phase II position

(*i*) Glenohumeral movement and rotation of the scapula take place in same 2 : 1 ratio.
(*ii*) Elevation of the acromial end of the clavicle does not occur any further.
(*iii*) The scapula rotates around a vertical axis for the second time by 10 degrees.
(*iv*) The clavicle now rotates in its long axis through about 30—40 degrees so that the conoid tubercle is directed downwards.
(*v*) In elevation of the arm in abduction, external rotation of the head of the humerus also takes place to effect the movement.

MOVEMENTS OF THE SHOULDER GIRDLE

The skeletal elements of the shoulder girdle are the two scapulae and the two clavicles, the latter negotiate the scapulae with the trunk through the sternoclavicular joints. This girdle is an incomplete one and the two upper limbs, one on each side, are connected to it through the shoulder joints. The scapula forms the principal element of the girdle in which it gives attachment to the upper limb and bring it in connection with the trunk through a crank-shaft, the clavicle through the acromioclavicular and the sternoclavicular joints. Thus any movement of the scapula is reflected back to its crank-shaft, the clavicle which moves between its joints, that is, the acromioclavicular and the sternoclavicular joints and vice versa. The movement of the scapula is also associated with the movement of the upper limb at the shoulder joint in most cases. Thus the movement of the shoulder girdle may be discussed under two heads, movements of the girdle unassociated with the movements of the shoulder joint or true girdle movement and the movement of the girdle associated with the movement of the shoulder joint.

Movements of the shoulder girdle unassociated with the movement of the shoulder joint or the true girdle movement. These movements can better be identified by observing some of the movements of the scapula. The following movements of the scapula are included under this headings:

Elevation and depression of the scapula.
Forward and backward movements of the scapula.

Elevation of the scapula. This is a movement in which the points of the shoulder are approximated towards the root of the neck as in shrugging the shoulder. In this movement the point of the shoulder is raised by elevation of the scapula as a whole, there is an angular movement at the acromio-clavicular joint in which the lateral end of the clavicle is raised and its sternal end rolls down on its intra-articular disc. This movement is checked by the tension of the capsular and the costoclavicular ligaments of the sternoclavicular joint and by the tension of the opposing groups of muscles. The muscles concerned in this movement are the *upper fibres of the trapezius* and the *levator scapulae* (the trapezius tries to rotate the scapula downwards, forwards and laterally whereas the levator scapulae causes the opposite movement and the resultant force being directed upwards).

Depression of the scapula. This is the reverse movement of the above and is brought about mostly by the weight of the limb assisted by *serratus anterior* and *pectoralis minor*. In this there is very little angular movement in the acromio-clavicular joint and the sternal end rolls up on the articular disc. This movement is checked by the tension of the sternoclavicular and interclavicular ligaments and by the tension of the opposing groups of muscles.

Forward movement of the scapula. In this movement the shoulder-ball moves forwards. The acromion moves forwards on the clavicular facet dragging the lateral end of the clavicle forwards and its sternal end together with the articular disc moves backwards. This movement is checked by the tension of the posterior sternoclavicular and the posterior fibres of the costoclavicular ligaments. Muscles concerned in this movement are the *serratus anterior* and the *pectoralis minor* assisted by the *latissimus dorsi*.

Backward movement of the scapula. This is a movement in which the vertebral borders of the scapulae are approximated to each other as in bracing back the shoulder. In this there is very little movement in the acromioclavicular joint whereas the sternal end of the clavicle together with the articular disc moves forwards. This movement is checked by the tension of the anterior sternoclavicular and the anterior fibres of the costoclavicular ligaments. The muscles concerned in this movement are the *trapezius* and the *rhomboidei*.

Movements of the girdle associated with the movement of the shoulder joint. These movements have been discussed along with the movement of the shoulder joint.

THE ELBOW JOINT

The Elbow joint is a ginglymus or a hinge joint and consists of two articulations: (1) humero-ulnar and (2) humero-radial. The articular surfaces concerned

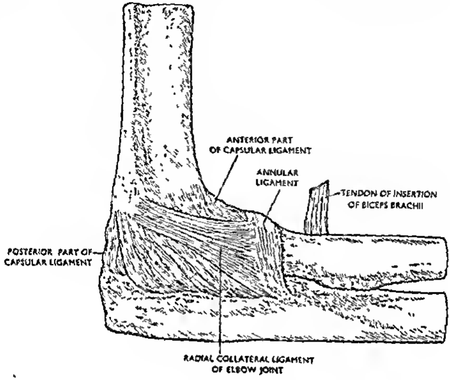


Fig. 457. The right elbow joint. Seen from the lateral side.

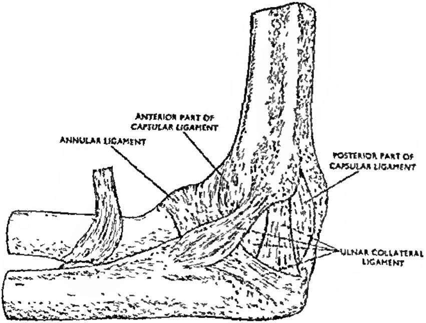


Fig. 458. The right elbow joint. Seen from the medial side.

are the trochela and the capitulum of the humerus on the one hand, and the trochlear notch of the ulna and the head of the radius on the other.

Ligaments of the joint—

(1) Capsular ligament.
(2) Ulnar (Medial) collateral ligament.
(3) Radial collateral (Lateral) ligament.

(1) **Capsular ligement.** The *fibrous capsule* surrounds the joint on all sides and is specially thickened on either side to form the ulnar collateral (medial) ligament on the medial side and the radial collateral (lateral) ligament on the lateral side. It is attached *proximally* to the antero-medial and antero-lateral surfaces of the humerus above the coronoid and the radial fossae.

At the sides it is attached to the epicondyles and posteriorly, to the posterior surface of the humerus above the olecranon fossa. *Distally* the capsule is attached to the anterior margin of the proximal, medial and lateral surfaces of the olecranon, to the medial and anterior margins of the coronoid process of the ulna and to the annular ligament of the radius.

The anterior part of the capsule is broad, thin and membranous and consists of of three sets of fibres. The most superficial fibres are oblique in direction and pass downwards and laterally from the medial epicondyle of the humerus to the annular ligament. The middle sets of fibres are vertical in direction and extend from the upper part of the coronoid fossa to the anterior aspect of the coronoid process of the ulna. The deep sets of fibres are transversely disposed and they intersect the preceding fibres at right angles.

The posterior part of the fibrous capsule is also thin and membranous and consists of transverse and oblique fibres.

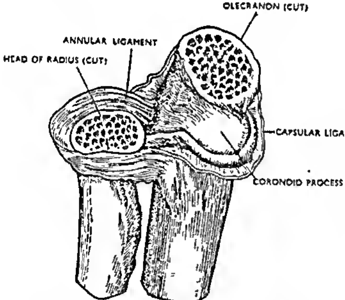


Fig. 459. The superior radio-ulnar joint. Seen from above after removing the head of the radius partially.

(2) **Ulnar Collateral (Medial) ligament.** It consists of three parts, thickened anterior and posterior parts and a thin intermediate part lying between them. The thickened anterior portion is attached above to the anterior part of the medial epicondyle of the humerus, and below to the anterior and medial margins of the coronoid process of the ulna. The thickened posterior portion is attached above to the lower and posterior part of the medial epicondyle of the humerus, and below to the medial margin of the olecranon process of the ulna. The thin intermediate portion ...ched above to the lower end of the medial epicondyle, in front to the anterior

band, behind to the posterior band and below to the oblique band of the ulnar collateral ligament. The oblique band forms a thickened band of fibres which stretches between the olecranon and the coronoid processes of the ulna. The medial ligament is covered anteriorly by flexor digitorum superficialis (sublimis) et flexor carpi ulnaris and medially by the triceps brachii muscle.

(3) **Radial Collateral (Lateral) ligament.** It is roughly triangular in shape the apex of which is attached above to the antero-inferior part of the lateral epicondyle of the humerus and below its base is attached to the lateral aspect of the annulur ligament and to the adjacent margins of the radial notch of the ulna. The ligament is strengthened by the origins of the supinator and the extensor carpi radialis brevis muscles.

Synovial membrane. It extends from the margin of the articular surface of the humerus and lines the coronoid, radial and the olecranon fossae on that bone and covers the flattened medial surface of the trochlea. It is reflected over the deep surface of the capsular ligament and lines the deep surface of the annular ligament. From the annular ligament it is reflected on to the neck of the radius and extends upwards up to the articular margin of the head of the radius. From the medial aspect of the neck of the radius it passes medially over the quadrate ligament to the lower margin of the radial notch of the ulna forming a cul-de-sac in this region.

Relations of the capsular ligament:

In front. Brachialis.

Behind. Triceps brachii and anconeus.

Laterally. Supinator and the common tendon of origin of the extensor muscles of the forearm.

Medially. Common tendon of origin of the flexor muscles and the flexor carpi ulnaris muscle.

Movements. Flexion and extension are the chief movements of the joint. The movements take place around a transverse axis that passes through the humeral epicondyles.

(1) *Flexion.* Here the joint moves anteriorly as in approximating the forearm to the arm. Muscles concerned are the biceps, brachialis and brachio-radialis. The common flexors also help in the process.

(2) *Extension.* Here the joint moves backwards as in straightening the forearm from a bent position. The muscles concerned are the triceps, anconeus and the common extensors.

Artery supply. Arteries are derived from the arterial anastomosis around the joint, and the branches are derived from the anterior and posterior descending branches of the arteria profunda brachii, anterior and posterior ulnar recurrent and the radial recurrent arteries.

Nerves. Two twigs from the median nerve, one from the ulnar nerve, one from the radial nerve and one from the muscular branch of the musculo-cutaneous nerve to the brachialis muscle, supply the joint.

THE RADIO-CARPAL OR THE WRIST JOINT

The radio-carpal or the wrist joint is a condyloid sub-group of the synovial joint and possesses a wide range of movement.

Parts entering into the articulation. As it is a condyloid joint the articular surfaces are so adapted that a biconvex ovoid fits into a biconcave elliptical articular surface. Superiorly the inferior surface of the lower end of the radius together with the triangular articular disc forms the biconcave elliptical surface and inferiorly the scaphoid, the lunate and the triquetral bones form the biconvex ovoid and the two articular surfaces articulate with each other to form the wrist joint.

Ligaments of the joint:

Capsular ligament.
Anterior or palmar radiocarpal ligament.
Anterior or palmar ulnocarpal ligament.
Posterior or dorsal radiocarpal ligament.
Lateral or radial collateral ligament.
Medial or ulnar collateral ligament.

Capsular ligament. *Superiorly*, it is attached to the lower end of the radius and the head of the ulna above the epiphyseal lines thus enclosing the lower epiphyses of the ulna and the radius, and to the margins of the articular disc. *Inferiorly*, the capsular ligament is attached to the carpal bones entering into the articulation.

Interiorly the capsular ligament is lined with synovial membrane and the joint cavity formed by it does not communicate with the intercarpal or with the inferior radio-ulnar joints.

Anterior or the palmar radiocarpal ligament. It is a broad membranous band situated on the anterior aspect of the capsular ligament. Superiorly it is attached to the anterior margin of the lower end of the radius and to the anterior aspect of the lower end of the ulna. Inferiorly it is attached to the anterior aspect of the scaphoid, lunate and the triquetral bones. Its fibres are directed downwards and medially.

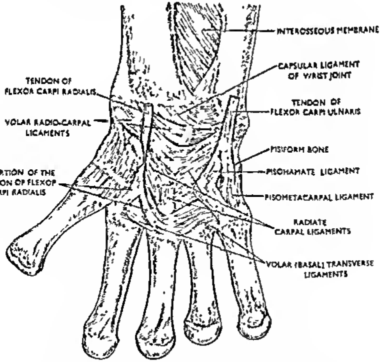


Fig. 460. The right radio-carpal, inter-carpal and the carpo-metacarpal joints. Seen from the front.

Anterior or palmar ulnocarpal ligament. This is a rounded band of fibres which connects the base of the ulnar styloid process and the anterior margin of the triangular articular disc of the distal radio-ulnar joint with the lunate and the triquetral bones.

Posterior or the dorsal radiocarpal ligament. It occupies the posterior of the capsular ligament and its fibres are directed downwards and medially.

It connects the posterior aspect of the lower ends of the ulna and radius with the posterior surfaces of the scaphoid, lunate and the triquetral bones. This is thinner than the anterior ligament.

Lateral ligament or the radial collateral ligament. It is attached above to the styloid process of the radius and below to the tubercle of the scaphoid and to the lateral aspects of the trapezium. It forms the floor of the anatomical snuff-box and the radial artery is intimately related with it.

Medial ligament or the ulnar collateral ligament. It connects the styloid process of the ulna with the triquetral and pisiform bones. It is in close relation with the dorsal cutaneous branch of the ulnar nerve.

Relations of the wrist joint. *Anteriorly* it is in relation with the tendons of the flexor digitorum profundus, flexor pollicis longus and the flexor carpi ulnaris and lying in between these tendons and the anterior radiocarpal ligament are the anterior interosseous vessels and nerves and the anterior carpal arch.

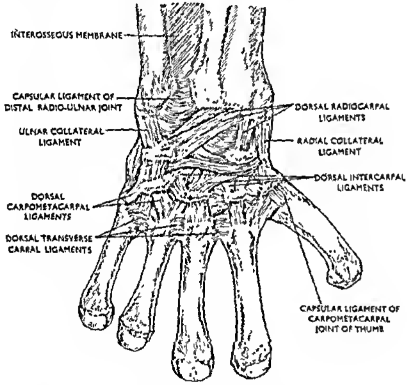


Fig. 461. The right radio-carpal, intercarpal and carpo-metacarpal joints. Seen from behind.

Posteriorly it is in relation with the following tendons from lateral to medial side, tensor carpi radialis longus et brevis, extensor pollicis longus, extensor digitorum, tensor indicis, extensor digiti minimi and intervening between the extensor digirum tendon and the posterior radiocarpal ligament are the posterior interosseous ssels and nerve and the posterior carpal arch.

Laterally it is related to the tendons of the abductor pollicis longus et extensor llicis brevis and intervening in between these tendons and the lateral ligament the radial artery.

Medially it is in relation to the dorsal cutaneous branch of the ulnar nerve which aches the medial aspect of the medial ligament by passing deep to the tendon of ie flexor carpi ulnaris muscle.

Movements of the joint. The movements of the joint are flexion, extension, adduction, abduction and circumduction. These movements at the wrist joint are associated with movement in the transverse intercarpal joint. The movement of flexion and extension takes place around a transverse axis whereas the movements of abduction and adduction take place around an antero-posterior axis.

Flexion is the forward movement of the joint in which the hand is approximated to the front of the forearm. The prime movers in this are the flexor carpi ulnaris, flexor carpi radialis and the palmaris longus. The long flexors of the digits also help in the process.

Extension or *backward movement* of the joint is produced by the extensor carpi ulnaris, extensor carpi radialis longus and the extensor carpi radialis brevis. The long extensors of the digits also help in the process.

Adduction or ulnar deviation of the hand is caused by the flexor et extensor carpi ulnaris.

Abduction or radial deviation of the hand is more restricted than the adduction because of the longer radial styloid process and is caused by the flexor carpi radialis, extensor carpi radialis longus et brevis, the abductor pollicis longus and the extensor pollicis brevis.

Circumduction is the combination of movements of flexion, extension, adduction and abduction following one after another in rapid succession.

Muscles concerned are those which produce the above movements.

Artery supply. Arteries supplying the joint are derived from the anterior and posterior carpal networks formed by the branches of the ulnar and radial arteries.

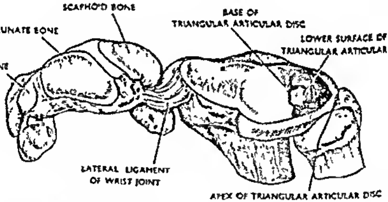


Fig. 462. The left radio-carpal joint. The carpus has been drawn apart laterally to show the lateral ligament.

Nerve supply. Nerves are derived from the anterior interosseous branch of the median, posterior interosseous branch of the radial and the dorsal cutaneous branch of the ulnar nerve.

N.B. The range of movement of flexion apparently seems to be more than the movement of extension but in reality the movement of extension has a wider range than the movement of flexion. The apparent movement of flexion of the wrist joint is due to the simultaneous flexion of the transverse carpal and the carpo-metacarpal joints. Rotation movement of the wrist joint is not possible because the elliptical ovoid formed by the proximal carpal bones has no advantage for such movement in its mechanism and any attempt to do so will cause a rent in the capsular ligament with subsequent dislocation. The absence of rotation movement in the wrist joint is well compensated by the pronation and supination of the forearm which take place in the superior and inferior radio-ulnar joints. In these movements the lower end of the radius and the triangular articular disc together with the hand rotate on the head

of the ulna. The direction of the anterior and posterior radiocarpal ligaments, both of which are directed downwards and medially, is well adapted to the implementation of these movements.

Anteriorly the wrist joint corresponds to the proximal crease opposite the front of the wrist joint. Medially the lower end of the styloid process of the ulna corresponds to the joint cavity. The relation between the two styloid processes is that the radial styloid is half an inch lower than the ulnar styloid process.

THE RADIO-ULNAR JOINTS

The ulna and the radius are connected together by three joints, proximal, distal and middle radio-ulnar joints. The proximal and the distal radio-ulnar joints are of synovial type whereas the middle one is a fibrous union. In the movement between the ulna and the radius these three joints work as a single unit. The axis of movement is a vertical oblique axis which passes from the head of the radius to the head of the ulna.

The proximal radio-ulnar joint. This is a pivot type of synovial joint in which the head of the radius forms the pivot which rotates in a osseo-fibrous ring formed by the radial notch of the ulna and the annular ligament. The annular ligament subserves the function of the capsular ligament and is lined internally by the synovial membrane. The joint cavity is continuous above with the elbow joint. The ligaments of the joints are the annular and the quadrate ligaments.

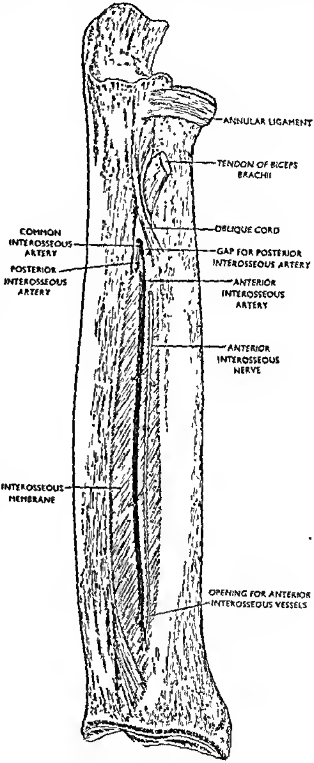


Fig. 463. The radio-ulnar joints. Seen from the front.

Annular ligament. It is a ring-shaped fibrous band which surrounds the head of the radius and is attached to the anterior and the posterior margins of the radial notch of the ulna. It forms about $\frac{4}{5}$ of the osseo-fibrous ring and its upper border blends with the capsular and the radial collateral ligaments of the elbow joint. Its inferior

margin remains free so as to form a tight collar around the neck of the radius. The synovial membrane that lines the lower part of the inner aspect of the annular ligament after reaching its lower margin is reflected on to the neck of the radius to which it is attached. The upper part of the annular ligament which surrounds the circumferential margin of the head of the radius is fibro-cartilaginous.

The annular ligament gives origin to some fibres of the supinator muscle and is related posteriorly to anconeus and to the interosseous recurrent vessels.

Quadrate ligament. It is a short quadrangular band that stretches between the lower border of the radial notch of the ulna and the neck of the radius above the radial tuberosity. It is lined superiorly by synovial membrane.

The Distal radio-ulnar joint. This is a synovial joint between the head of the ulna and the ulnar notch of the lower end of the radius. The joint is completed inferiorly by a triangular articular disc which separates the distal radio-ulnar joint from the radio-carpal (wrist) joint. The joint is surrounded by a capsular ligament which is lined internally by the synovial membrane.

The triangular articular disc. It is a fibro-cartilaginous disc, triangular in shape, having a base, an apex, anterior and posterior margins and upper and lower surfaces. Its base is attached to the smooth ridge separating the ulnar notch of the radius and the distal articular surface of the lower end of the radius. Its apex is attached to the base of the styloid process on the distal aspect of the head of the ulna. Its anterior and posterior margins give attachment to the capsular ligament. Its upper surface is in contact with the semilunar area on the distal aspect of the head of the ulna and comes to the formation of the distal radio-ulnar joint; its lower surface is in contact with the medial part of the lunate bone, and with the triquetral bone when the hand is adducted and comes to the formation of the radio-carpal joint.

The Middle radio-ulnar joint. This is a fibrous union between the bodies of the ulna and the radius and the union is effected by the oblique cord and the interosseous membrane.

Oblique Cord. This is a cord-like narrow, oblique, fibrous band directed downwards and laterally, and is attached above and medially to the lateral side of the ulnar tuberosity, and below and laterally, to the shaft of the radius below the radial tuberosity.

Interosseous membrane. It is a strong, thin, membranous sheet that fills up the interosseous space between the radius and the ulna. Most of its fibres are directed downwards and medially and are attached laterally to the interosseous or the medial border of the shaft of the radius and to the posterior margin of the ulnar notch of the lower end of the radius. Medially it is attached to the lateral or the interosseous border of the ulna. Superiorly it is deficient and extends upto a point *about an inch below the lower part of the radial tuberosity. Inferiorly it extends* as far as the distal radio-ulnar joint. Some of the fibres of the interosseous membrane, particularly in its distal part, are directed downwards and laterally from ulna to the radius. The interosseous membrane is broader in the middle and narrower both above and below.

Relations. Anteriorly in its upper three-fourths it is covered laterally by the flexor pollicis longus and medially by the flexor digitorum profundus; in its lower one-fourth it is covered by the pronator quadratus. The anterior interosseous vessels and nerve descend vertically downwards between the flexor pollicis longus and the flexor digitorum profundus; the anterior interosseous vessels do not reach as low as to the lower end of the membrane but they pierce through it at a distance of about an inch from the lower end to pass to the back of the forearm.

Posteriorly it is covered by the supinator, abductor pollicis longus, extensor pollicis brevis, extensor pollicis longus and the extensor indicis from above downwards; the posterior interosseous nerve comes into relation with it in the lower part of the forearm.

Superiorly it is deficient so as to form a gap between its upper border and the oblique cord through which the posterior interosseous vessels pass to the back of the forearm.

Inferiorly it blends with the capsular ligament of the inferior radio-ulnar joint.

Functions. (i) It keeps the ulna and the radius in contact with each other. (ii) It provides extra surface area between the ulna and the radius for muscular attachments. It helps in weight transmission from the radius to the ulna and through the latter to the humerus.

Movements of the radio-ulnar joints. The movements in these joints are supination and pronation which occur through a vertical axis passing through the head of the radius to the head of the ulna.

The muscles concerned in supination are the supinator and the biceps brachii; the biceps brachii works as a supinator when the elbow is semiflexed. The brachio-radialis also helps in supination from mid-prone position. The muscles concerned in pronation are the pronator teres and the pronator quadratus. The brachio-radialis also helps in bringing the supinated forearm in pronation.

THE INTERCARPAL JOINTS

The joints between the carpal bones consist mainly of three articulations: (a) articulation between the bones of the proximal row, (b) articulation between the bones of the distal row and (c) the mid-carpal joint between the bones of the proximal and the distal rows.

Articulation between the bones of the proximal row. The scaphoid, lunate and the triquetral bones articulate with one another by transverse bands of fibrous tissue and by two interosseous ligaments. The anterior transverse band is known as the *palmar ligament* while the posterior band is called the *dorsal ligament*. Of the two interosseous ligaments, one is interposed between the scaphoid and the lunate and the other between the lunate and the triquetral bones.

The *pisiform bone* articulates with anterior aspects of the triquetral bone by three ligaments, capsular, pisohamate and pisometacarpal ligaments.

The *capsular ligament* surrounds the articular surfaces of the triquetral and the pisiform bones and is lined internally by the synovial membrane. It forms a separate synovial joint.

The *pisohamate ligament* connects the pisiform bone with the hook of the hamate. The *pisometacarpal ligament* extends from the pisiform bone to the base of the fifth metacarpal bone. Both the above ligaments are fibrous expansions from the tendon of the flexor carpi ulnaris which is inserted into the anterior aspect of the pisiform bone.

Articulation between the bones of the distal row. The bones of the distal row, that is, the trapezium, trapezoid, capitate and the hamate articulate with one another by dorsal and palmar ligaments and by three interosseous ligaments.

Mid-carpal or transverse carpal joint. The distal articular surfaces of the bones of the proximal row, except the pisiform bone, form a concave articular surface which articulates with the convex articular surface formed by the bones of the distal row. The ligaments of the joint are the palmar, dorsal, lateral and medial ligaments.

The palmar and the dorsal ligaments are short bands of fibres which extend from the bones of the proximal to the distal rows and each occupies the corresponding aspect of the bones. The palmar ligaments connecting the head of the capitate bone with the bones adjacent to it, consist of short radiating bands and are known as *radiate carpal ligaments*.

The lateral or the radial collateral ligament connects the trapezium with the scaphoid while the medial or the ulnar collateral ligament connects the triquetral with the hamate bone.

THE CARPO-METACARPAL JOINTS

These are the joints formed between the distal carpal bones (trapezium, trapezoid, capitate and the hamate) and the bases of the metacarpal bones. The first carpo metacarpal joint is a saddle joint and enjoys wide range of movements while the rest of the joints are of plain type and each consists of palmar, dorsal and interosse ous ligaments and is lined internally by synovial membrane.

Carpo-metacarpal joint of the thumb. The bones entering into this articulation are the distal surface of the trapezium and the base of the first metacarpal bone. It is a saddle joint and consists of a capsular ligament which surrounds the articular surfaces of the two bones. It is lined internally by synovial membrane.

The ligaments of the joint are capsular, palmar, dorsal and lateral.

Capsular ligament. It forms a thick but loose membrane that surrounds the margins of the articulating surfaces of the two bones. It is lined internally by the synovial membrane which forms a separate joint cavity.

Palmar ligament. It is an oblique band directed downwards and medially and is attached above to the palmar aspect of the trapezium and below to the ulnar side of the base of the first metacarpal bone.

Dorsal ligament. It is similarly disposed like the palmar ligament and is attached above to the dorsal aspect of the trapezium and below to the ulnar side of the base of the first metacarpal bone.

Lateral ligament. It is a strong band that connects the lateral aspects of the two bones.

Nerve supply. It is supplied by the median nerve.

Movements. It consists of flexion, extension, adduction, abduction, opposition and circumduction. Flexion and opposition movements are caused by the opponens pollicis and the flexor pollicis longus et brevis. Extension is caused by the two extensors of the thumb, namely, extensor pollicis longus et brevis. Abduction is caused by the abductor pollicis longus et brevis while adduction is caused by the adductor pollicis. Circumduction is the combination of all the movements which follow one after the other.

Carpo-Metacarpal joints of the medial four digits. These are plain types of synovial joints. These joints are supported by indefinite capsular ligaments and by palmar, dorsal and interosseous ligaments. The joint cavities formed by the reflections of the synovial membrane are often continuous with each other and with the intercarpal joints. The joint between the hamate bone and the fourth and the fifth metacarpal bones may form a separate joint cavity.

Dorsal ligaments. They form short bands which extend between the carpal and the metacarpal bones on the dorsal aspect. Except the fifth metacarpal each of the other three metacarpal bones is connected with two bands. The second metacarpal bone is connected with trapezium and trapezoid, the third with trapezoid and capitate and the fourth with capitate and hamate. The fifth metacarpal bone is connected with a single band that extends between it and the hamate bone.

Palmar ligaments. *The palmar ligaments are similar in arrangement like* the dorsal ones except that the third metacarpal bone has three bands of connection, medial, lateral and intermediate. The medial band extends from the hamate, the lateral from the trapezium and the intermediate from the capitate.

Interosseous ligaments. They form short bands which connect the contiguous distal margins of the capitate and hamate bones with the adjoining surfaces of the third and the fourth metacarpal bones.

THE INTERMETACARPAL JOINTS

The contiguous surfaces of the bases of the second, third, fourth and the fifth metacarpal bones articulate with each other to form the intermetacarpal joints. They form plane types of synovial joints and their joint cavities are continuous with each other and with the carpo-metacarpal joints. The ligaments of these joints are palmar, dorsal and interosseous.

The **palmar** and the **dorsal ligaments** form transverse bands that extend from the base of one bone to the other on the palmar and the dorsal aspects respectively.

The **interosseous ligaments** form short bands that extend between the contiguous surfaces of the bases of the two adjacent bones distal to their articulating surfaces.

Movements. The intermetacarpal joints permit some simple gliding movements between the two articulating bones.

THE METACARPO-PHALANGEAL JOINTS

Each is a condyloid joint and is formed by the head of the metacarpal bone and the base of the proximal phalanx. The ligaments of the joint are the palmar and collateral ligaments. The deep transverse ligament of the palm forms an additional ligament.

Palmar ligaments. They occupy the anterior aspect of the joint and form thickened fibro-cartilaginous bands. Distally, they are attached to the palmar aspect of the base of the proximal phalanx and proximally, they gain their principal attachment to the deep transverse ligament of the palm and partial attachment to the head of the metacarpal bone. Their attachment to the base of the proximal phalanx is more firm than their attachment to the head of the metacarpal bone. On either side they blend with the collateral ligament. Their palmar surface forms a shallow groove for the reception of the flexor tendons of the digit and on either side their margins give attachment to the fibrous sheath of the flexor tendon. Their dorsal surface forms a part of the artitular area.

Collateral ligaments. The collateral ligaments are strong fibrous bands on either side of the articulation and proximally, they are attached to the dorsal tubercle and to the depressed area on the sides of the head of the metacarpal bone. Distally, they are attached, on either side, to the base of the proximal phalanx.

Transverse ligaments of the palm. They form three distinct transverse bands which connect the palmar ligaments of the metacarpo-phalangeal joints of the second, third, fourth and the fifth digits.

Nerve supply. They are supplied by the deep branch of the ulnar nerve.

Movements. Their principal movements are flexion and extension although they have slight side to side movements in the form of adduction and abduction.

Synovial cavity of the carpal joint. The synovial cavity is very much extensive and forms an irregular transverse cavity, the main cavity, which intervenes between bones of the proximal and distal rows (except the pisiform). Two prolongations extend upwards, one on each side of the lunate bone and three prolongations extend downwards between the four bones of the distal row. The distal prolongation between the trapezium and the trapezoid bones sometimes communicates with the carpo-metacarpal joint below owing to the absence of interosseous ligament between the two bones. Similarly, the prolongation between the capitate and the hamate may also communicate with the carpo-metacarpal joint below.

Nerve supply. It is supplied by the median, ulnar and the posterior interosseous nerves.

Movements. The principal movements of the joint are flexion and extension carried out by the flexors and the extensors of the wrist joint.

THE INTERPHALANGEAL JOINTS

There are two interphalangeal joints, proximal and distal, in each of the medial four fingers, and one in the thumb. The interphalangeal joints are hinge type of synovial joints. The ligaments of the joints are the same as in the metacarpophalangeal joints and they are capsular, palmar and collateral ligaments.

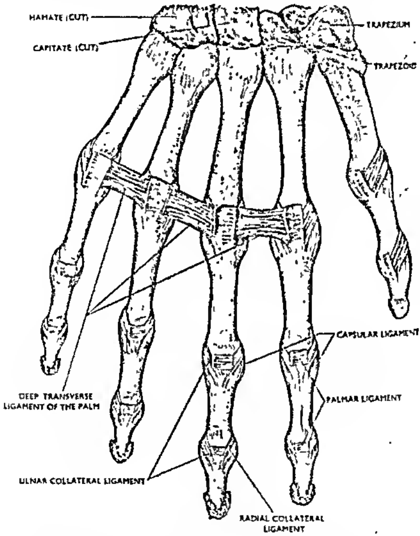


Fig. 464. The metacarpo-phalangeal and the inter-phalangeal joints of the left side. Seen from the front.

Capsular ligament. It surrounds the bony ends entering into the articulation. It is particularly thin over the dorsal aspect and is mostly replaced by the extensor expansion.

Palmar ligaments. Each palmar ligament is a fibro-cartilaginous structure which is attached firmly to the palmar aspect of the base of the distal bone and loosely to the head of the proximal bone. It forms a strong thick band on the palmar aspect of the joint and blends with the capsular ligaments.

Collateral ligaments. They are two oblique bands one on each side of the joint. Each band extends from the dorsal aspect of the side of the head of the proximal bone to the palmar aspect of the side of the base of the distal bone.

Artery supply. The interphalangeal joints are supplied by branches from the digital arteries.

Nerve supply. The interphalangeal joint of the thumb is mostly supplied by the median nerve and to a small extent by the radial nerve, the joints of the index and middle fingers by the median nerve alone; the joints of ring finger are supplied by the ulnar and median nerves and those of the little finger by the ulnar nerve alone.

Movements. The movements permitted in the inter-phalangeal joints are flexion and extension.

Flexion. The movement of flexion, as in approximating the tips of the fingers to the palm, is more free than the extension. The muscles producing this movement are the flexor digitorum superficialis (sublimis) and the flexor digitorum proprofundus, the former directly concerns the proximal interphalangeal joint and the latter, the distal interphalangeal joint.

Extension. This is the opposite movement of the movement of flexion as in opening out the closed hand. This movement is restricted by the tension of the palmar and collateral ligaments and by the tension of the long flexor tendons. The muscles concerned in this movement are the extensor digitorum (chief muscle), interossei and the lumbricals.

MOVEMENTS OF THE THUMB

The skeleton of the thumb consists of two phalanges and the first metacarpal bone which articulates with the trapezium. Thus the thumb consists of three joints, interphalangeal, metacarpo-phalangeal and carpo-metacarpal, and most of the movements are of composite nature involving some from of movement in all the above joints. However, movements permitted are not of the same type in all the three joints. Thus the movements of the thumb are discussed below separately under each of the three joints of the thumb except the movement of opposition which has been dealt under a separate head.

Movement at the interphalangeal joint. The inter-phalangeal joint is a typical hinge joint and the movements permitted in the joint are flexion and extension.

Flexion. In this the terminal or the distal phalanx is appoximated towards the proximal plalanx as in bending the thumb towards its palmar surface and the range of movement is about 90°. This movement is usually associated with the movement (flexion) of the metacarpo-phalangeal joint. The muscle concerned in this movement is the flexor pollicis longus.

Extension. This is the reverse of the movement of flexion and the degree of movement is variable. The chief muscle causing this movement is the extensor pollicis longus which is assisted by the extensor pollicis brevis, abductor pollicis brevis and the adductor pollicis through their connections with the long extensor of the thumb.

Movements at the metacarpo-phalangeal joint. The movements at the metacarpo-phalangeal joint are flexion, extension, adduction, abduction and rotations.

Flexion. In this movement the thumb moves across and parallel to the palm of the hand as in bending the thumb towards its palmar surface so as carry it across

the front of the palm of the hand. This movement is associated with the movement of the carpo-metacarpal joint. The main muscles concerned in this movement are the flexor pollicis brevis and the adductor pollicis. The abductor pollicis brevis and the flexor pollicis longus also assist in this movement.

Extension. This is the reverse movement of the former and is produced by the extensor pollicis brevis and the extensor pollicis longus.

Abduction. The movement of abduction of the thumb at the metacarpophalangeal joint takes place at a plane at right angle to the plane of the palm, as in carrying the thumb away from its contact with radial border of the index finger. The muscle concerned in this movement is the abductor pollicis brevis.

Adduction. In this movement the thumb is brought back to lie in contact with the radial border of the index finger from the position of abduction. The muscle concerned in this movement is the adductor pollicis.

Rotation. The flexion is associated with medial rotation while the movement of extension is associated with the lateral rotation of the thumb. The main muscle causing the medial rotation is the opponens pollicis. The lateral rotation is caused by extensor pollicis longus and abductor pollicis longus.

It appears that the final position of abduction and extension is not the same and these movements occur in different planes.

Movements at the carpo-metacarpal joint. The movement permitted in this joint are the same as in the metacarpo-phalangeal joint such as flexion, extension, adduction, abduction and medial and lateral rotations.

Muscles concerned in the above movements are the same as in the metacarpophalangeal joint except that the opponens pollicis comes in flexion and the abductor pollicis longus in abduction in addition.

Movement of opposition. This is an intricate movement of the thumb in which all its three joints are involved. This is a combination of movements in which the thumb is abducted, medially rotated, flexed and adducted at the carpo-metacarpal and metacarpo-phalangeal joints and is either flexed or extended in the interphalangeal joint as in pinching something between the thumb and any other finger. This is the most useful movement of the thumb which enables the human hand to acquire its masterly supremacy in picking and gripping different objects.

THE JOINTS OF THE PELVIS

THE LUMBO-SACRAL JOINT

The bony parts entering into the articulation consist of the bodies of the fifth lumbar and the first sacral vertebrae together with the intervertebral disc intervening between them, and the articular processes of the two vertebrae.

The articulation between the bodies of the fifth lumbar and the first sacral vertebrae is a secondary cartilaginous joint and the articulation takes place through the medium of the intervertebral disc. Its ligaments are the anterior and posterior longitudinal ligaments, which from the principal bond of union between the two vertebrae, and the lateral lumbo-sacral and ilio-lumbar ligaments which are accessory support to the joint.

The *anterior* and the *posterior longitudinal ligaments* cover the corresponding aspects of the bodies of the two vertebrae and are attached to the adjoining margins of the two vertebrae and to the intervertebral disc.

The *lateral lumbo-sacral ligament* is attached above to the lower border of the transverse process of the fifth lumbar vertebra and to the lateral aspects of the ala of the sacrum inferiorly. It represents the superior costo-transverse ligament of the dorsal region.

The *ilio-lumbar ligament* is a triangular ligament directed backwards and laterally and is attached above to tip of the transverse process of the fifth lumbar vertebra and below to the inner lip of the iliac crest behind the quadratus lumborum.

The spinous process of the fifth lumbar vertebra is connected to the spinous process of the first sacral vertebra by the supraspinous and interspinous ligaments.

The laminae of the fifth lumbar vertebra are connected with the laminae of the first sacral vertebra by the lowest ligamentum flavum.

The articulation between the inferior articular processes of the fifth lumbar vertebra and the superior articular processes of the first sacral vertebra is a synovial joint and their articular margins give attachment to the capsular ligament which is lined internally by synovial membrane.

N.B. **The lumbo-sacral intervertebral disc.** Like other intervertebral discs the lumbo-sacral intervertebral disc is a fibro-cartilaginous disc which intervenes between the bodies of the fifth lumbar and the first sacral vertebrae. It corresponds in shape with the bodies of the vertebrae between which it is placed and is much thicker in front than behind and thus resembles a wedge between the above two vertebrae and contributes in building up the lumbar convexity.

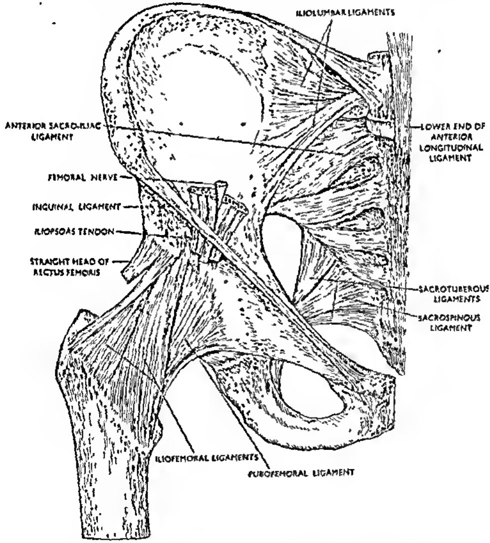


Fig. 465. The right sacro-iliac and the hip joints. Seen from the front.

In structure, like other intervertebral discs, the lumbo-sacral intervertebral disc consists of a central gelatinous mass known as the *nucleus pulposus* and a peripheral fibro-cartilaginous part known as the *annulus fibrosus* which is composed mainly of of concentrically arranged fibrous rings with a few cartilage cells embedded in it.

The nucleus pulposus together with the annulus fibrosus is sandwitched between two thin plates of hyaline cartilage and thus the architecture of the disc as a buffer between the two vertebrae is well secured.

Developmentally, during early embryonic life, the notochordal tissue in the intervertebral position at first proliferates rapidly and then degenerates to form a gelatinous mass of tissue from which the nucleus pulposus is derived. Subsequently the notochordal tissue is invaded by the surrounding fibro-cartilaginous tissue which results in the formation of the fibro-cartilaginous disc having contained within it the nucleus pulposus. The lumbo-sacral intervertebral disc occupies its position in between the 24th and the 25th vertebrae in the growing vertebral column.

Functionally it acts as a buffer in absorbing mechanical shock by distributing the pressure equally between the vertebrae and thus behaves like a water-cushion.

Relations. All the intervertebral discs form a part of the anterior boundary of the intervertebral foramen and thus the lumbro-sacral intervertebral disc forms a part of the anterior boundary of the fifth lumbar intervertebral foramen and is intimately related to the fifth lumbar nerve. It also forms a part of the anterior boundary of the vertebral canal and comes in relation with the corda equina of the spinal cord being *separated by the spinal meninges and the posterior longitudinal ligament.* Anteriorly, opposite the median plane, it is in relation with the median sacral artery and the hypogastric plexus of nerves, and more laterally, on either side, with the sympathetic trunk, internal iliac vessels, fifth lumbar and obturator nerves, all these structures being separated by the anterior longitudinal ligament. The ureter lies in front of the internal iliac artery in this situation.

Movements. The movements permitted in this joint are the same as in other vertebral joints and consists of flexion and extension around a transverse axis, lateral flexion or right and left abduction around a ventro-dorsal axis and rotation (right and left) around the vertical spinal axis.

Flexion :-

Rectus abdominis.
Psoas major et minor.
Internal and external oblique muscles of the abdomen.

Extension :-

Sacrospinalis.
Multifidus.
Quadratus lumborum.

Right abduction or lateral flexion :-
Right quadratus lumborum.
Right sacrospinalis.

Left abduction or lateral flexion :-
Left quadratus lumborum.
Left sacrospinalis.

Right rotation :-
Left external oblique muscle of abdomen.
Right internal oblique muscle of abdomen.

Left rotation :-
Right external oblique muscle of abdomen.
Left internal oblique muscle of abdomen.

Artery supply. It is supplied by the branches from the ilio-lumbar and the superior lateral sacral arteries.

Nerve supply. It is supplied by branches from the fourth and the fifth lumbar nerves. It also receives some filaments from the sympathetic nerves.

THE SACRO-COCCYGEAL JOINT

It is a secondary cartilaginous joint and the bony parts entering into the articulation are the apex of the sacrum and the base of the coccyx together with an articular disc intervening between the two. The ligaments of the joint are the anterior, posterior, lateral sacro-coccygeal and the intercornual ligaments.

The **anterior sacro-coccygeal ligament** is a short ligament that connects the anterior aspect of the lower part of the sacrum with the anterior aspect of the coccyx.

The **posterior sacro-coccygeal ligament** consists of superficial and deep fibres. The superficial posterior sacro-coccygeal ligament extends from the margins of the hiatus sacralis to the dorsal aspect of the coccyx. In its course downwards it closes the hiatus sacralis and completes the lower part of the sacral canal. The deep posterior sacro-coccygeal ligament is attached above to the posterior aspect of the fifth sacral vertebra and below to the back of the coccyx. The filum terminale is attached to the back of the first coccygeal vertebra between these two ligaments.

The **intercornual ligament** connects the cornua of the coccyx with the cornua of the sacrum.

The **lateral sacro-coccygeal ligament** connects the rudimentary transverse process of the coccyx with the inferior lateral angle of the sacrum and forms a foramen through which the fifth sacral nerve passes.

Artery supply. It is supplied by the inferior lateral sacral and the median sacral arteries.

Nerve supply. The nerves are the fourth and the fifth sacral and the coccygeal nerves.

Movements. Moderate degree of forward and backward movements take place in this joint which are more marked in case of the female, specially during pregnancy.

Intercoccygeal joints. They are fixed joints of the nature of the secondary cartilaginous joint and the anterior and posterior ligaments connect them together.

THE SACRO-ILIAC JOINT

It falls under the sub-group of plane type of synovial joint although the movements permitted in this joint are very much limited and the articulating surfaces are irregular.

The bony parts entering into the articulation are the auricular surface of the ilium and the auricular articular surface on the lateral mass of the sacrum. Both the articular surfaces present irregularities in the form of depressions and elevations which reciprocally fit with each other so as to permit a bony interlocking which restricts movements, but at the same time increases stability of the joint. The auricular articular surface of the sacrum is covered by hyaline cartilage but its counterpart on the ilium is lined by a layer of fibrocartilage and thus differing from ordinary synovial joint in which the hony parts entering into articulation are lined by articular cartilage (hyaline cartilage).

The joint is completely surrounded by a capsular ligament which is lined internally by the synovial membrane. The other ligaments of the joint are as follows :-

(1) Anterior sacro-iliac ligament.
(2) Posterior sacro-iliac ligament.
  (a) Interosseous sacro-iliac ligament.
  (b) Short posterior sacro-iliac ligament.
  (c) Long posterior sacro-iliac ligament.
(3) Sacrotuberous ligament. } Acceroray ligaments.
(4) Sacrospinous ligament. }

(1) *Anterior sacro-iliac ligament.* It is a strong band of ligament which covers

the antero-inferior part of the joint and is attached to the adjoining margins of the two bones.

(2) *Posterior sacro-iliac ligament.* It is a very strong and a thick band of ligament which covers the postero-superior aspect of the joint and consists of three strata of fibres namely, (*a*) interosseous sacro-iliac ligament, (*b*) short posterior sacro-iliac ligament and (*c*) the long posterior sacro-iliac ligament, from within outwards.

(*a*) *Interosseous sacro-iliac ligament.* It consists of short, thick and very strong fibres which fill up the narrow interosseous spaces adjoining the postero-superior aspects of the joint cavity and connect the two bones (sacrum and ilium) together.

(*b*) *Short posterior sacro-iliac ligament.* It consists of short oblique and horizontal fibres which connect the two bones together and lie superficial to the interosseous ligament. Its upper fibres are horizontal while its posterior fibres are oblique which extend medially and downwards from the postero-superior iliac spine to the upper two sacral transverse tubercles.

(*c*) *Long posterior sacro-iliac ligament.* Postero-lateral to the short posterior sacro-iliac ligament is the long posterior sacro-iliac ligament which runs vertically downwards from the posterior superior iliac spine to the third and the fourth transverse sacral tubercles. Its lateral fibres are blended with the sacrotuberous ligament.

(3) *Sacrotuberous ligament.* It is attached above to the posterior superior iliac spine and to the back and side of the lower part of the sacrum and the coccyx. Below it is attached to the medial margin of the ischial tuberosity and to the inferior margin of the ramus of the ischium; the portion attached to the latter ends in a free falciform border and is known as the *falciform process.* The sacrotuberous ligament is pierced by twigs from the coccygeal branches of the inferior gluteal artery. From its posterior surface the lower fibres of the gluteus maximus muscle takes its origin while some of its lower superficial fibres become continuous with the tendon of origin of the biceps femoris and is supposed to be the fibrous remnant of the embryological head of the same muscle.

(4) *Sacrospinous ligament.* It is a triangular ligament the apex of which is attached to the tip of the ischial spine while its base is attached to the lower part of the lateral margin of the sacrum and to the upper lateral margin of the coccyx in front of the sacrotuberous ligament. Its fibres are closely intermixed with the fibres of the sacrotuberous ligament and are closely blended with the coccygeus muscle which lies in front of it and of which it is supposed to be the fibrous remnant. The sacrospinous and the sacro-tuberous ligaments together covert the greater and the lesser sciatic notches into the corresponding foramina.

Relations. Anteriorly the fibrous capsule of the joint is in relation with the lumbosacral nerve trunk, the first sacral nerve and the superior gluteal artery medially while the ilio-psoas muscle is related to it laterally. The superior gluteal artery usually intervenes between the lumbosacral trunk and the first sacral nerve. The ilio-lumbar artery ascends upwards and laterally in front of the capsule. The obturator nerve also descends downwards and laterally in front of it and intervenes between the medial edge of the psoas and the fourth lumbar nerve which comes down to join with the lumbosacral trunk. Posteriorly it is related to the gluteus maximus laterally and to the sacrospinalis muscle medially.

Artery supply. The branches from the superior gluteal, iliolumbar and the upper lateral sacral arteries supply the joint.

Nerve supply. The nerves are derived from the anterior primary rami of the first and second sacral nerves, superior gluteal nerve and branches from the obturator and the posterior primary rami of the first and second sacral nerves.

Movements. Although the movement is much restricted slight antero-pos- or rotary movements are permitted in this joint and this is greater in case of fe- -e, specially during pregnancy.

The Symphysis pubis

The medial or symphyseal surfaces of the pubic bones articulate with each ıer by the intervention of a plate-like fibrocartilage and form the pubic symphy- . The bony surfaces entering into the articulation are covered by a thin layer of aline cartilage and are connected together through the medium of the fibrocarti- ;inous disc which may contain a cavity within. It is a secondary cartilaginous joint and consists of superior and inferior pubic and the anterior pubic ligaments.

The **superior pubic ligament** connects the superior aspects of the two pubic bones. Their fibres are less numerous and are weak in consistency.

THE JOINTS OF THE INFERIOR EXTREMITY

THE HIP JOINT

The hip joint is a ball and socket sub-group of the diarthrodial joint. The bony parts entering into the articulation are the head of the femur which forms the 'ball' and the acetabular cavity which forms the 'socket' and receives the spheroidal head of the femur. The head of the femur is everywhere covered by the articular cartilage except at its centre where its forms a pit for the attachment of the ligament of the head of the femur (Ligamentum teres femoris). The acetabular cavity is an in-complete socket having a notch inferiorly—the acetabular notch which is completed in the recent state by the attachment of the transverse acetabular ligament which bridges across the acetabular notch. The acetabular cavity is lined by articular cartilage except at its bottom where it forms a horse-shoe shaped non-articular area known as the acetabular fossa and is occupied by a pad of fat and the ligament of the head of the femur.

The head of the femur is comparatively smaller than its socket and consequently the whole of it is received into the acetabular cavity and this makes the joint well secured but at the same time this arrangement restricts the range of movement.

Ligaments of the joint

(1) Capsular ligament.
 (*a*) Ilio-femoral ligament.
 (*b*) Ischio-femoral ligament.
 (*c*) Pubo-femoral or pubo-capsular ligament.

(2) Ligament of the head of the femur.

(3) Transverse acetabular ligament.

(4) Acetabular labrum.

(1) **Capsular ligament.** The capsular ligament of the hip joint is very strong and dense and consists of an outer *fibrous* and an inner *synovial stratum.*

The *fibrous stratum* of the capsular ligament consists of inner circular and outer longitudinal fibres which are more numerous and surround the joint on all sides. The *inner circular fibres* are less numerous, run circularly deep to the outer longitu-dinal fibres and they have no bony attachment. They cause an hourglass constric-tion within the capsule and constitute the *zona orbicularis* of the capsular ligament. The *outer longitudinal fibres* run mostly longitudinally from the hip bone to the femur and form the main bulk of the fibrous stratum. Some of the deepest longitudinal fibres after being distally attached to the femur are reflected upwards upon the neck and proceed towards the articular margin of the head. These reflected fibres which are collected into bundles, particularly on the lower and upper aspects of the neck, are called the *cervical ligaments* or the *retinacula.*

The fibrous stratum of the capsular ligament is supported by expansions from the rectus femoris, the gluteus minimus and the piriformis muscles and is strengthened by three supplemental bands, namely, the *ilio-femoral*, the *ischio-femoral* and the *pubo femoral* ligaments, specially developed to meet particular stress and strain to which the capsule is subjected.

Attachments. Proximally the capsular ligament is attached to the acetabular margin except superiorly where it extends for about 1/4 inch beyond the acetabular margin; anteriorly it blends with the acetabular labrum and inferiorly it blends with the transverse acetabular ligament.

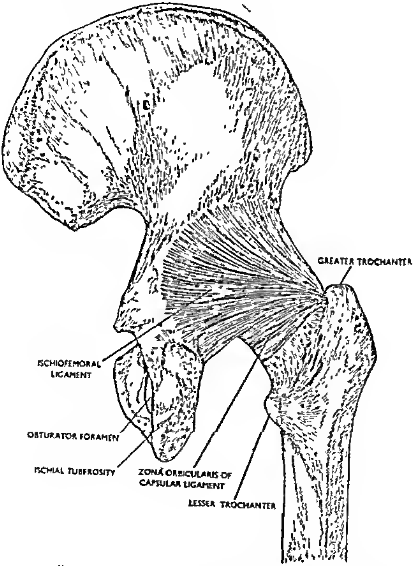


Fig. 466. The right hip joint. Seen from behind.

Distally it surrounds the neck of the femur and is attached anteriorly to the trochanteric line; posteriorly it encloses about ⅔ of the neck and is attached to it about half-an-inch above the trochanteric crest; superiorly it is attached to the neck close to its junction with the greater trochanter and inferiorly it is attached to neck above the root of the lesser trochanter.

Thus it appears that the whole of the anterior part, and about ⅝ of the posterior part of the neck is intracapsular. The epiphyseal cartilage for the head is intracapsular while those of the trochanters are extra-capsular.

The supplemental bands of the capsular ligament. The *ilio-femoral ligament.* It occupies the anterior aspect of the capsular ligament and is triangular in shape, the apex of which is attached to the lower part of the anterior inferior iliac spine and to the adjoining part of the acetabular margin. Its base consists of upper and lower thick bands and a thin intermediate band. The lower band which is vertical in direction is attached to the lower part of the trochanteric line whereas its oblique upper band is attached to the upper part of the trochanteric line; its intermediate band is attached to the trochanteric line in between the two former bands. The fibres of this ligament are incorporated with the fibres of the capsular ligament. The ligament resembles the inverted letter 'Y' in appearance and hence it is also described as Y-shaped ligament.

The ischio-femoral ligament. It forms a broad band of fibres which covers the posterior aspect of the capsule and is attached above to the ischium below and behind the acetabular margin. Below, majority of its fibres are blended with the capsular ligament and a few are attached to the base of the greater trochanter.

The pubo-femoral ligament. It is triangular in shape, the base of which is attached to the ilio-pubic eminence, superior ramus of the pubis and to the obturator crest. Its apex blends with the capsular ligament and with the deep aspect of the lower band of the ilio-femoral ligament.

All the three supplemental bands become taut when the hip joint is extended.

Opening in the capsular ligament. There is usually only one opening in the capsular ligament and is situated between the lower band of the ilio-femoral ligament and the pubo-femoral ligament. This deficiency in the capsule is well compensated by the overlying strong tendon of psoas major muscle in this situation. A bursal protrution of the synovial membrane through this opening intervenes between the capsular ligament and the tendon of the psoas major muscle and serves as a bursa for the same. Posteriorly occasionally the attachment of the capsular ligament to the neck of the femur may be deficient and a bursal protrution of the synovial membrane under the lower free edge of the fibrous capsule serves as a bursa for the tendon of obturator externus muscle.

The synovial stratum of the capsular ligament. The synovial membrane of the capsular ligament lines the interior of the fibrous capsule and then is reflected onto the neck of the femur and extends as far as the articular cartilage of the head. It also covers both aspects of the acetabular labrum and contribute in the following special formations:

(1) Tubular sheath for the ligament of the head of the femur
(2) Sheath for the acetabular pad of fat
(3) Bursa for the tendon of psoas major muscle
(4) Bursa for the tendon of obturator externus muscle
(5) The folds of synovial membrane overlying the cervical ligament or the retinacula carry blood vessels for the supply of the femoral head.

Relations of the capsular ligament. *Anteriorly* the capsular ligament is related to the pectineus, the tendon of the psoas major, the iliacus and the straight head of the rectus femoris muscles from medial to the lateral side; the pectineus separates the capsule from the femoral vein and the psoas tendon from the femoral artery; the femoral nerve lies in the groove between the iliacus and the psoas.

Posteriorly. The capsular ligament is related to the piriformis, gemellus superior, tendon of obturator internus, gemellus inferior and obturator externus in order from above downwards. The tendon of obturator externus separates the capsule from the quadratus femoris and is accompanied by the ascending branch of the medial circumflex femoral artery; the nerve to the quadratus femoris intervenes between the capsule and the common tendon of obturator internus et gemelli; postero-superiorly the sciatic nerve is separated from the capsule by the common tendon of obturator

Traced vertically at the sides it is found to be attached above on to the two walls of the articular surface of the condyle of the femur; laterally its upper attachment is the same as on the medial side except that it forms a *subpopliteal recess* between the tendon of the popliteus and the bone. Inferiorly the synovial membrane descends as two folds or walls, one on each side, from each femoral condyle; the central fold is found to be attached below to the inner edges of the articular surface of the corresponding tibial condyle; the peripheral wall or fold is attached inferiorly to the *upper and outer edge* of the corresponding meniscus and then its line of continuity is broken and the membrane is again found to be attached to the *lower* and *outer edge of the miniscus* and finally forming a small cul-de-sac is attached to the articular edge of the corresponding condyle of the tibia.

From the attachments of the synovial membrane it appears that the synovial cavity formed by it is incompletely subdivided into several inter-communicating compartments. Seen from behind the synovial cavity is found to be divided into medial and lateral parts together with an intersynovial space posteriorly. Due to the intervening meniscus each of the lateral and medial synovial cavities is subdivided into upper and lower parts; the upper one lies above the meniscus while the lower one lies below it and the two parts communicate with each other centrally around the thin free edge of the meniscus. Moreover posteriorly the lateral synovial cavity sends out a recess, the *subpopliteal recess*, which acts as a bursa between the bone and the tendon of the popliteus.

Ligamentum patellae. It is the central portion of the common tendon of the quadriceps femoris muscle and extends from the lower end of the patella to the tuberosity of the tibia. It is attached above to the adjoining margin and to the rough depression in the lower part of the posterior surface of the patella. Below it is attached to the upper part of the tubercle of the tibia.

Oblique posterior ligament. It is a broad fibrous band attached above to the lateral part of the intercoodylar line and to the lateral condyle of the femur and below it blends with the capsular ligament of the joint. It consists of a strong fasciculus which is derived from the tendon of the semimembranosus muscle.

Arcuate ligament. It is attached to the lateral condyle of the femur and passes downwards to fuse with the capsular ligament. An anterior and a posterior band of fibres converge from the upper and lower ends of the ligament respectively to unite together and form the retinaculum of the ligament which is attacbed to the styloid process of the fibula.

Tibial collateral (Medial) ligament. It is a broad flat baod of fibres, attached above to the whole of the medial epicondyle of the femur immediately below the adductor tubercle; below to the medial condyle, the upper and posterior part of the medial surface and the adjoining medial border of the shaft of the tibia. Its anterior margin remains free whereas its posterior margin is attached to the medial meniscus between its femoro-tibial attachments. Its superficial surface is crossed by the tendons of the sartorius, gracilis and semitendinosus, a bursa intervening. *Morphologically the medial ligament represents the degenerated portion of the adductor magnus.* Its deep surface covers the inferior medial genicular vessels and nerves and the anterior part of semimembranosus.

Fibular collateral (Lateral) ligament. It is cord-like and is attached above to the lateral epicondyle of the femur immediately above the groove for the tendon of the popliteus. Below it is attached to the lateral side of the head of the fibula, in front of its styloid process. Deep to the ligament there lies the tendon of the popliteus and the inferior lateral genicular vessels and nerves.

Cruciate ligaments. The cruciate ligaments are well named because they cross each other like the limbs of the letter "X", in the interval between the two condyles of the femur. According to their situation within the joint, they are named anterior and posterior cruciate ligaments.

Anterior cruciate ligament. It is attached below to the intermediate rough area on the proximal surface of the tibia, just in front of the anterior attachment of the lateral meniscus (semilunar cartilage). Above it is attached to the posterior part of the medial surface of the lateral condyle of the femur.

Posterior cruciate ligament. It is attached below to the posterior part of the posterior intercondylar area of the tibia immediately behind the posterior end of the medial meniscus (semilunar cartilage). Above it is attached to the anterior part of the lateral surface of the medial condyle of the femur.

Functions of the cruciate ligaments. Like all other ligaments the cruciate ligaments *bind the femur and the tibia together and prevent their displacement. They also help the collateral ligaments to prevent bending of the joint to either side.* In the internal derangement of the knee joint while testing the integrity of the cruciate ligaments it is found that if the anterior cruciate ligament is ruptured the tibia shows undue forward mobility; similarly when the posterior cruciate ligament is ruptured it shows undue backward mobility. On this basis it has long been known that the *anterior cruciate ligament prevents the tibia being carried too far forward while the posterior cruciate ligament prevents the tibia being carried too far backwards.*

According to recent views* the cruciate ligaments together with the semilunar cartilages *act as guide-ropes to keep the tibia on its winding path during flexion and extension of the knee joint.* The menisci (semilunar cartilages) are in continuity with the cruciate ligaments and Sir Harry Platt described this arrangement as the "figure of eight" anatomy of the knee joint and that they work together.

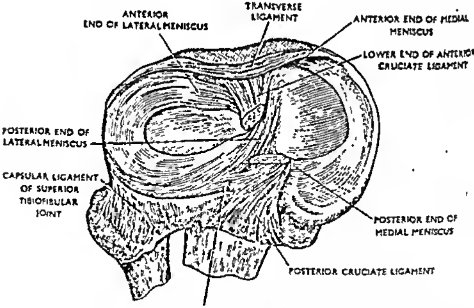


Fig. 467. The left superior tibio-fibular joint and the upper end of the left tibia to show the inter-condylar attachments.

Transverse ligament. It connects the anterior convex margin of the lateral to the anterior end of the medial semilunar cartilage.

Coronary ligament. They are short vertical fibres derived from the capsular ligament and connect the peripheral margin of the menisci (semilunar cartilages) with the tibia.

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* Arthur J. Helfet, J. Bone and Joint Surg., May, 1959.

Posterior meniscofemoral ligament (Ligament of Wrisberg). It is a oblique band of fibres that extends from the posterior end of the lateral meniscus (semilunar cartilage) and follows the posterior aspect of the posterior cruciate ligament and is attached to the lateral surface of the medial condyle of the femur along with the posterior cruciate ligament.

Anterior meniscofemoral ligament (Ligament of Humphry). It is a comparatively thinner band of oblique fibres that connects the posterior end of the lateral meniscus (semilunar cartilage) to the lateral surface of the medial condyle of the femur passing anterior to the posterior cruciate ligament.

Menisci (Semilunar cartilages). Semilunar cartilages are two crescentic plates of fibro-cartilaginous discs which are placed on the condylar surface of the tibia. They deepen the surface upon which the femoral condyles roll. Each semilunar cartilage presents two fibrous extremities or horns which are attached to the rough intercondylar area of the tibia. They are thick towards the circumference of the joint and thin towards the centre of the joint. Both surfaces are smooth and measure about 1·3cm. at the widest part. Each semilunar cartilage covers the peripheral two-thirds of the corresponding articular surface of the tibia.

Medial meniscus (semilunar cartilage). It is somewhat semicircular in shape and is broader behind than in front. Its anterior horn is attached to the anterior part of the intercondylar area of the tibia, in front of the anterior cruciate ligament. Its posterior end or horn is attached to the posterior intercondylar area, in front of the posterior cruciate ligament and behind the posterior horn of the lateral meniscus (semilunar cartilage). Its peripheral border is attached to the capsular ligament and is firmly adherent with the deep surface of the medial ligament of the knee joint.

Lateral meniscus (semilunar cartilage). It is almost circular in form. Its anterior end is attached in front to the intercondylar area of the tibia, behind and lateral to the anterior cruciate ligament. Its posterior end is attached behind to the intercondylar area of the tibia just in front of the posterior end of the medial semilunar cartilage. Its posterior part is grooved by the tendon of the popliteus. It is separated from the lateral ligament by a gap which transmits the tendon of the popliteus and the inferior lateral genicular vessels and nerves.

Functions of the menisci or the semilunar cartilages. The menisci or the semilunar cartilages are specially designed *to close the incongruities* brought about with the change in contact between the articulating surfaces of the femur and the tibia during active movements of the joint and are also responsible for making *adequate contact* between them during any static position. They are greatly *responsible for the perfect oiling and greesing mechanism of the joint.* They act as buffers in absorbing shock during extreme flexion and extension and thereby prevent bony injuries. Together with the cruciate ligaments they are made into a "figure of eight" which *forms a mechanism for the rotatory movements of the knee joint* in which the cruciate ligaments act as guiding-ropes.

Relations of the knee joint:

Anteriorly. It is covered by the quadriceps femoris tendon—the expansions from the vastus lateralis and vastus medialis occupy the antero-lateral and antero-medial part of the joint respectively.

Postero-medially. With the sartorius and the gracilis.

Postero-laterally. By the tendon of the biceps femoris with the lateral popliteal nerve on its medial side.

Posteriorly. The popliteal artery with the accompanying lymph glands descends downwards on the oblique posterior ligament, the popliteal vein lies on the postero-medial aspect of the artery; the medial popliteal nerve lies posterior to both the vessels. Both the vessels and the nerve are overlapped by the two heads of the gastrocnemius muscle under cover of which on the lateral side, the plantaris muscle

forms an additional relation. **On the medial** side the medial head of the gastrocnemius and the semimembranosus muscles come into relation with the capsular ligament.

Movement of the knee joint. The principal movement of the joint are flexion and extension with slight medial and lateral rotations. The movement of flexion and extension takes place around a transverse axis whereas the rotation occurs around a vertical axis that passes through the lateral condyle just medial to its centre.

Flexion. Here the leg is carried backwards towards the thigh, that is, as in approximating the back of the leg to the back of the thigh. This movement of flexion is associated with a slight lateral rotation of the femur. The muscles concerned are biceps femoris, semimembranosus and semitendinosus. The gracilis, sartorius and popliteus assist in the process.

Extension. Here the leg is carried forwards so as to put the leg in the same line with the thigh. This movement is associated with slight medial rotation of the femur. The quadriceps femoris is the main muscle in concern to produce the movement but the tensor fasciae latae may also assist in the process.

At the end of the extension, with the medial rotation of the femur, the cruciate ligaments become taut and wind around each other, the tibial and fibular collateral ligaments are also taut, the articulating surfaces become more congruent and the quadriceps femoris is relaxed and further extension of the joint is prevented. In this position the knee joint is said to be "locked" which makes it more stable.

Medial rotation. Popliteus, semimembranosus, semitendinosus, sartorius and gracilis are the muscles which cause medial rotation of the femur at the end of the extension.

Lateral rotation. Biceps femoris causes lateral rotation of the femur at the starting of flexion from the position of full extension in which the knee joint is locked. The popliteus taking its fixed point on the tibia rotates the femur laterally so as to unlock the "locked" knee and then the other flexors do the rest of the movement.

N.B. Rotation occurs throughout the whole range of movement of the knee joint and not during the extremes of flexion and extension as was thought previously. Arthur J Helfet, J. Bone and Joint Surg., May, 1959.

Artery supply. Arteries supplying the knee joint are derived from the genicular branches of the popliteal artery, descending genicular branch of the femoral artery, descending branch of the lateral circumflex femoral artery and the anterior tibial recurrent artery.

Nerve supply. *Femoral, lateral popliteal, medial popliteal and obturator* nerves—each provides branches which together are about ten in number. (1) The *femoral nerve* supplies the joint through branches which proceed from the nerve to the vastus lateralis, vastus medialis and vastus intermedius muscles. These nerves pierce the fibres of the quadriceps femoris muscle and supply the proximal and anterior part of the joint.

(2) The *lateral popliteal nerve.* It gives out (*i*) the superior and inferior lateral genicular nerves which accompany the corresponding artery and end in the capsular ligament; and (*ii*) the recurrent articular nerve which accompanies the anterior tibial recurrent artery supplies the distal and anterior part of the capsule.

(3) *Medial popliteal nerve.* It supplies the joint with superior and inferior medial genicular nerves and middle genicular nerves which accompany the corresponding genicular arteries and end in the capsule.

(4) *Obturator nerve.* The posterior division of the obturator nerve descends on the postero-medial aspect of the popliteal artery and ends by piercing the oblique posterior ligament of the knee joint.

Bursae around the knee joint:

In front of the knee joint

(1) Sub-cutaneous prepatellar bursa intervenes between the lower part of the patella and the skin. It does not communicate with the joint cavity.

(2) Sub-cutaneous infrapatellar bursa intervenes between the lower part of the tubercle of the tibia and the skin. It does not communicate with the joint.

(3) Deep infrapatellar bursa intervenes between the upper part of the tibia and the ligamentum patellae. It does not communicate with the joint.

(4) Supra-patellar bursa is a large one and usually communicates with the joint cavity and intervenes between the quadriceps femoris tendon and the lower part of the shaft of the femur.

On the lateral side of the knee joint

(1) One is interposed between the lateral head of the gastrocnemius and the capsule. It usually communicates with the joint.

(2) One is interposed between the lateral ligament and the tendon of the biceps femoris. It does not communicate with the joint.

(3) One is placed between the lateral ligament of the knee joint and the tendon of the popliteus. It may communicate with the joint cavity.

(4) One is interposed between the tendon of the popliteus and the lateral condyle of the femur. It usually communicates with the joint cavity.

On the medial side of the knee joint

(1) One bursa intervenes between the medial head of the gastrocnemius and the capsule. It may communicate with the joint cavity.

(2) Tibial inter-tendinous bursa intervenes between the medial ligament of the knee joint and the sartorius, gracilis and the semitendinosus muscles. It has no connection with the joint cavity.

(3) One is interposed between the medial ligament of the knee joint and the semimembranosus muscle. It has no connection with the joint cavity.

(4) One is present between the tendon of the semimembranosus and the medial condyle of the tibia.

(5) One may be situated between the tendons of the semimembranosus and semitendinosus. It has no connections with the joint cavity.

THE TIBIO-FIBULAR ARTICULATIONS

The leg-bones, that is, the tibia and the fibula, form a combined surface area by being united together both at their ends and opposite the intermediate position. Superiorly, the head of the fibula articulates with the fibular facet of the tibia to form a plane type of synovial joint, the *superior tibio-fibular joint*. Inferiorly, the rough triangular area on the medial side of the lower end of the fibula articulates with the fibular notch of the lower end of the tibia to form a fibrous joint, the *inferior tibio-fibular syndesmosis*. In the intermediate position the two bones are *united together by an interosseous membrane* to form a fibrous type of joint.

Superior tibio-fibular joint. This is a plane type of synovial joint formed between the flat facet on the head of the fibula and the similar facet on the postero-inferior part of the lateral condyle of the tibia. The ligaments of the joint are capsular, anterior and posterior.

Capsular ligament. It is attached to the margins of the articulating surfaces of the two bones and is lined internally by the synovial membrane. There may occasionally be an opening in the capsular ligament and the joint cavity may be in communication with the popliteal recess of the knee joint. The tendon of the popliteus is intimately related to the postero-superior part of the joint.

Anterior ligament. It consists of two or three small fibrous bands which run upwards and medially from the anterior part of the head of the fibula and are attached to the adjoining part of the lateral condyle of the tibia.

Posterior ligament. It consists of a thick band on the posterior part of the joint and ascends upwards and medially from the back of the head of the fibula to be attached to the adjoining part of the tibia.

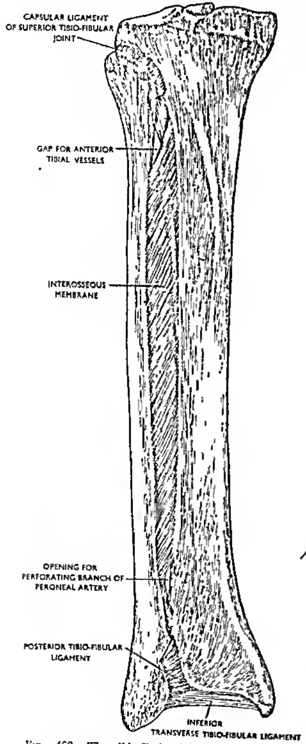

Fig. 468. The tibio-fibular joints of the left side Seen from behind.

Movement. The movement of the superior tibio-fibular joint is associated with the movement of the talocrural (ankle) joint. The smaller degree of widening of the tibio-fibular mortise during dorsi-flexion and its springing back to normality during plantar-flexion of the talocrural joint is associated with some *gliding movement* in the superior tibio-fibular joint.

Artery supply. It is supplied by branches from the arterial anastomosis around the knee joints.

Nerve supply. It is supplied by small branches from the *lateral popliteal nerve* and by twigs from the nerve to the popliteus from the *medial popliteal nerve.*

Inferior tibio-fibular syndesmosis. It is a fibrous joint in which the fibular notch at the lower end of the tibia articulates with the rough triangular area on the medial side of the lower end of the fibula by an interosseous ligament. Inferiorly, the base of the interosseous ligament just falls short of the margins of the common articular surface, the tibio-fibular mortise formed by the tibia and fibula, by about one-fourth inch. This small interosseous recess is occupied by a fold of synovial protrusion from the talocrural joint. The distal ends of this non-ligamentous area of the tibia and the fibula may occasionally be covered by articular cartilage. Superiorly, the interosseous ligament is continuous with the crural interosseous membrane. In addition to the interosseous ligament this joint is strengthened by the anterior (anterior inferior) and posterior (posterior

inferior) tibio-fibular ligaments and by the transverse (inferior transverse) tibio-fibular ligament.

Anterior tibio-fibular ligament. This is a flattened band of fibres which runs downwards and laterally from the anterior margin of the fibular notch of the tibia to the anterior margin of the rough triangular area on the medial aspect of the lower end of the fibula.

Posterior tibio-fibular ligament. It also runs downwards and laterally from the posterior margin of the fibular notch of the tibia to the posterior border of the rough triangular area on the medial side of the lower end of the fibula.

Inferior transverse ligament (Inferior transverse tibio-fibular ligament). It forms a thick transverse band which is attached to the whole length of the posterior edge of the inferior articular surface of the lower end of the tibia and to the upper part of the malleolar fossa of the fibula. This ligament forms a part of the tibio-fibular mortise and articulates with the posterior half of the lateral border of the trochlear surface of the talus.

Movement. Very limited spring-movement is permitted in this joint and this is associated with the dorsi-flexion and plantar-flexion of the talocrural joint.

Artery supply. It is supplied by branches from the anterior and posterior tibial and from the peroneal arteries.

Nerve supply. It is supplied by twigs from the anterior and posterior tibial nerves and from the nerve to the popliteus.

Crural Interosseous membrane. It is a strong fibrous membrane that stretches between the interosseous borders of the tibia and the fibula. Its fibres run downwards and laterally from the tibia to the fibula. Superiorly it just falls short of reaching the superior tibio-fibular joint whereas inferiorly it becomes continuous with the interosseous ligament of the inferior tibio-fibular syndesmosis. It intervenes between the anterior and the posterior compartments of the leg and presents two apertures, one at its upper end and the other at its lower part. The upper opening transmits the anterior tibial artery whereas the lower one transmits the perforating branch of the peroneal artery. Some of its fibres at its upper end, which form the upper boundary of the upper opening, run downwards and medially from the fibula to the tibia. Posteriorly it is related to the tibialis posterior and flexor hallucis longus whereas anteriorly it is related to the anterior tibial artery, the deep peroneal (ant. tibial) nerve and to the extensor muscles of the leg.

THE TALOCRURAL (ANKLE) JOINT

The talocrural (ankle) joint is a diarthrodial articulation of the ginglymus or hinge variety.

The bony parts entering into the articulation are the lower end of the tibia and its malleolus, the malleolus of the fibula, and the trochlear, lateral and medial surfaces of the talus. The lower end of the tibia, its malleolus, the malleolus of the fibula and the inferior transverse tibiofibular ligament together form a mortise for the reception of the body of the talus.

Ligaments of the joint

(1) Capsular, (2) Anterior and posterior, (3) Deltoid, (4) Lateral. (*a*) Anterior and posterior talofibular, (*b*) Calcaneofibular.

Capsular ligament. It surrounds the joint and is attached above to the borders of the articular surfaces of the tibia and to the borders of the articular surfaces of the medial and lateral malleoli. Below it is attached to the dorsum of the neck of the talus a little in front of the trochlear surface and elsewhere it is attached close to the margins of the articular surfaces.

Anterior ligament. It is a broad membranous layer attached above to the anterior margin of the lower end of the tibia and below to the talus a little in front of its superior articular surface.

Posterior ligament. It is attached above to the posterior margin of the articular surface of the tibia. Below it is attached to the talus behind its superior articular surface.

Deltoid ligament. It is a dense and strong band of fibres, triangular in shape with its apex directed upwards and base downwards. It consists of two sets of fibres, superficial and deep.

The superficial set of fibres is attached above to the margins of the medial malleolus of the tibia and from this attachment the fibres descend downwards and pass in three directions. The anterior most fibres descend downwards and forwards to be attached to the tubercle of the navicular bone and the medial margin of the spring ligament (plantar calcaneonavicular). The middle fibres descend perpendicularly downwards and are attached to the whole length of the sustentaculum tali of the calcaneum. The posterior fibres pass backwards and laterally to be attached to the medial side of the talus and to its medial tubercle.

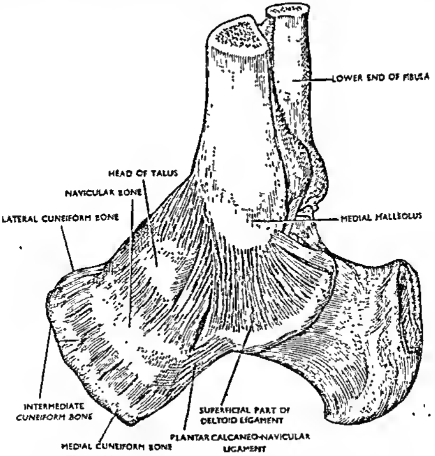

Fig. 469. The right ankle joint. Seen from the medial side.

The deep set of fibres is attached above to the depression at the lower border of the medial malleolus of the tibia and descends downwards to be attached to the non-articular part of the medial surface of the talus.

The deltoid ligament is crossed by the tendon of tibialis posterior and flexor digitorum longus.

Anterior talo-fibular ligament. It is attached above to the anterior margin of the lateral malleolus of the fibula and then passes medially and downwards to be attached to the front of the lateral articular surface and to the lateral side of the neck of the talus.

Calcaneo-fibular ligament. It is cord-like and is attached above to the notch on the lower border of the lateral malleolus of the fibula and below to the tubercle on the lateral surface of the calcaneum. It is crossed by the tendons of the peroneus longus et brevis muscles.

Posterior talo-fibular ligament. It is attached above to the lower part of the malleolar fossa of the fibula and below to the posterior tubercle of the talus.

Relations of the ankle joint. *Anteriorly* the ankle joint is in relation with the tibialis anterior, extensor hallucis longus, anterior tibial vessels and nerve, the tendons of the extensor digitorum longus and peroneus tertius from medial to lateral side.

Posteriorly from medial to lateral side it is in relation with tibialis posterior, flexor digitorum longus, posterior tibial vessels and nerve and flexor hallucis longus. In the groove on the posterior aspect of the lateral malleolus of the fibula there lies the tendons of the peroneus longus and peroneus brevis muscles.

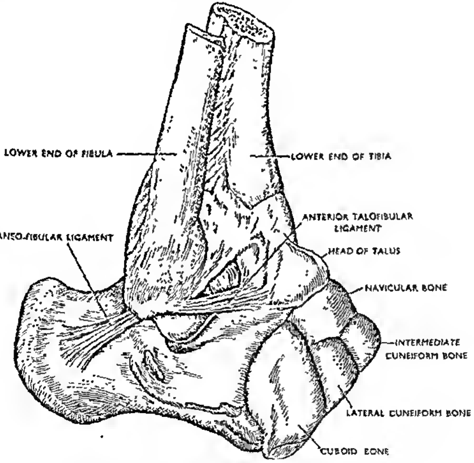

Fig. 470. The right ankle joint seen from the lateral side.

Movements of the ankle joint. The chief movements of the joint are dorsiflexion and plantar-flexion and they occur around a transverse axis that passes across the tip of the lateral malleolus, and in its course medially, it lies a little below the tip of the medial malleolus.

Dorsi-flexion. In this the angle between the lower part of the front of the leg and the dorsum of the foot is diminished. Muscles concerned in this movement are the tibialis anterior (which plays the most important role in this movement), extensor digitorum longus, peroneus longus and the peroneus tertius.

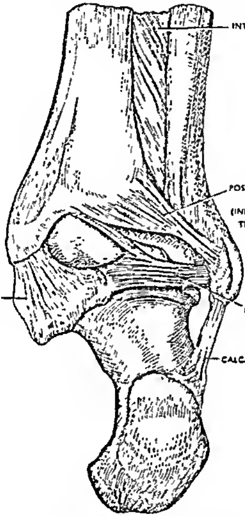

Fig. 471. The right ankle joint. Seen from behind.

Plantar-flexion. In this the angle between the lower part of the leg and the dorsum of the foot is increased, the heel is raised and the toes are pointed downwards. Muscles concerned are the gastrocnemius and the soleus (chief effector), peroneus longus and brevis, the plantaris and tibialis posterior, the flexor hallucis longus and the flexor digitorum longus.

Artery supply. Malleolar branches from the anterior tibial and the peroneal arteries supply the ankle joint.

Nerve supply. Nerves are derived from the anterior and posterior tibial nerves.

TARSAL JOINTS

The tarsal joints may be subdivided into posterior tarsal, mid-tarsal and ... al joints.

POSTERIOR TARSAL JOINTS. The posterior tarsal joints consist of two articulations, one between the talus and the calcaneum and the other between the talus, calcaneum and the navicular bones. The latter has been described under mid-tarsal joint.

Subtalar (Talo-calcaneal) Joint. The subtalar (talo-calcaneal) joint is a plane type of articulation and the bony parts entering into the articulation are the concave posterior calcaneal facet on the undersurface of the body of the talus and the convex posterior facet for the talus on the superior surface of the calcaneum. The ligaments of the joint are the following:

Capsular ligament. It surrounds the articular surfaces of the two bones and consists of short slips of fibres which are lined by a thin fibrous layer. It is enveloped by a synovial membrane and the joint cavity does not communicate with any other tarsal joints.

Anterior talo-calcaneal ligament. It connects the antero-inferior part of the neck of the talus with the anterior part of the superior surface of the calcaneum.

Posterior talo-calcaneal ligament. It extends from the posterior tubercle of the talus to the posterior part of the superior surface of the calcaneum adjoining the posterior facet of the calcaneum.

Medial talo-calcaneal ligament. It connects the medial tubercle of the talus with the posterior part of the sustentaculum tali of the calcaneum. This is blended with the fibres of the deltoid ligament.

Lateral talo-calcaneal ligament. It extends from the lateral tubercle of the talus to the lateral surface of the calcaneum, above and in front of the calcaneofibular ligament.

Interosseous talo-calcaneal ligament. This is the strongest ligament of the joint and is attached superiorly to the sulcus tali and inferiorly to the sulcus calcanei. It may be divisible into two parts, anterior and posterior. The anterior part forms the posterior ligament of the talocalcaneonavicular joint and its posterior part forms the anterior ligament of the talocalcaneal joint. These two parts are fused to form a single band but laterally they are separated into two parts by less dense fibres. This ligament forms the principal bond of union between the two bones and it becomes taut during inversion of the foot and thereby it prevents over-inversion of the same.

Movements of the posterior tarsal joints. The chief movements of the joint are the inversion and eversion of the foot. In inversion the medial margin of the foot is raised whereas in eversion the lateral margin of the foot is raised. These movements occur in association with the movements in the mid-tarsal joints and have been discussed along with them.

Mid-tarsal joint. The mid-tarsal joints consist of talo-calcaneo-navicular and calcaneo-cuboid joints.

Talocalcaneonavicular joint. This is the largest of the tarsal joints and it consists of a cup-shaped fossa into which the head of the talus fits. The cup-shaped articular fossa is formed by the concave posterior facet of the navicular bone, the anterior and middle facets for the talus of the calcaneum and the plantar calcaneonavicular (spring ligament) and the calcaneonavicular part of the bifurcated ligaments. The ligaments of the joint are the following:

Plantar calcaneonavicular ligament (spring ligament). It forms a broad, thick band which connects the anterior margin of the sustentaculum tali with the plantar aspect of the navicular bone. Its medial margin blends with the fibres of the deltoid ligament. Its dorsal or superior surface supports the head of the talus whereas its plantar or inferior surface is directly in contact with the tendon of the tibialis posterior medially and the tendons of the flexor hallucis longus and the

flexor digitorum longus laterally. **By its position** it prevents flattening of the longitudinal arch of the foot and the tendons of the tibialis posterior, flexor digitorum longus and the flexor hallucis longus effectively support it from below which prevent it from being stretched.

Bifurcated ligaroent. It is a Y-shaped ligament the stem of which is attached to the rough anterior part of the calcaneum. Its two limbs form the medial and lateral bands of fibres. The lateral band is attached in front to the medial aspect of the dorsal surface of the cuboid and is known as the medial calcaneocuboid ligament. The medial band is attached in front to the lateral part of the dorsal surface of the navicular bone and is known as the lateral calcaneonavicular ligament.

Dorsal talonavicular ligament. It connects the dorsal aspect of the neck of the talus with the dorsal aspect of the navicular bone.

Calcaneocuboid joint. This resembles a saddle-shaped joint and the bony parts entering into the articulation are the anterior surface of the calcaneum and the posterior surface of the cuboid. The following are the ligaments of the joint:

Capsnlar ligament. It surrounds the joint and is supported by the other ligaments of the joint. It is lined internally by the synovial membrane and the joint cavity is distinct from other tarsal joints.

Bifurcated ligament. It has already been described.

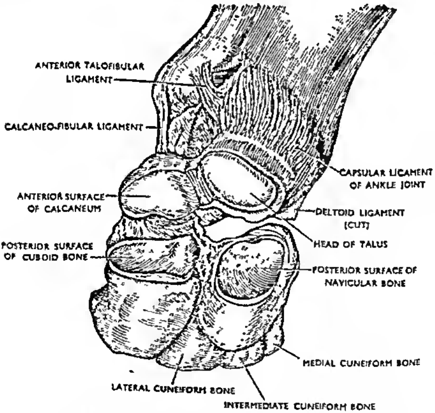

Fig. 472. The opened-up mid-tarsal joints of the right side. Seen from the front.

Dorsal calcaneocuboid ligament. It connects the anterior part of the dorsal surface of the calcaneum with the dorsal surface of the cuboid.

Long plantar ligament. It is the strongest and the longest ligament of all he tarsal ligaments and is attached, posteriorly, to the plantar aspect of the calca-

neum in front of the lateral and medial tubercles, and anteriorly to the ridge on the plantar aspect of the cuboid bone. From its anterior end it gives out processes which are attached to the bases of the second, third and the fourth metatarsal bones.

Short plantar ligament. It is a short and thick oblique band which connects the anterior tubercle of the calcaneum and the groove in front of it with the posterior part of the ridge on the plantar aspect of the cuboid bone. It lies under cover of the long plantar ligament.

Relations. *Dorsally* the mid-tarsal joint is related to the tendons of tibialis anterior, extensor hallucis longus, extensor digitorum longus, and peroneus tertius, and is covered by the fleshy fibres of extensor digitorum brevis. The arteria dorsalis pedis and the anterior tibial nerve cross the joint from behind forwards opposite the first intermetatarsal space dorsally. On the *plantar aspect* the joint is related to the tendons of flexor hallucis longus, flexor digitorum longus, flexor digitorum accessorius and to the lateral and medial plantar vessels and nerves. *Laterally* it is related to the tendons of peroneus longus and brevis whereas *medially* the tendons of tibialis posterior and flexor digitorum longus are related to it from behind forwards.

Movement. The chief movements in the mid-tarsal joints are *inversion* and *eversion* in which the medial and the lateral margins of the foot are raised respectively. The axis around which the movement occurs is an oblique one which passes upwards, forwards and medially from the heel to the neck of the talus passing in its course through the tarsal canal (sinus tarsi). Both the movements of inversion and eversion are rotatory movement around the above axis and are associated with movements in other tarsal joints and in the ankle joint. The movement of inversion is associated with plantar flexion (extension) of the ankle joint and adduction of foot whereas the movement of eversion is associated with dorsiflexion of the ankle and abduction of the foot.

Muscles causing inversion and eversion. Muscles that are attached to the medial margin of the foot, that is, *tibialis anterior* and *tibialis posterior* are the invertors whereas the muscles attached to the lateral margin of the foot, that is, *peroneus longus* and *brevis* are evertors of the foot.

Artery supply. The *talo-calcaneonavicular joint* is supplied by branches from the medial plantar and dorsalis pedis arteries. The calcaneocuboid joint is supplied by the tarsal and metatarsal branches from the arteria dorsalis pedis and from the plantar arteries.

Anterior tarsal joints. The anterior tarsal joints consist of cuneonavicular, cuneo-cuboid and the intercuneiform joints.

CUNEO-NAVICULAR JOINT. In this articulation the navicular bone articulates in front with the three cuneiform bones. The ligaments of the joint are dorsal, plantar and medial.

Dorsal ligament. The dorsal ligaments are three in number and they extend from the dorsal aspect of the navicular to the same aspect of the three cuneiform bones.

Plantar ligaments. They have similar arrangement like the dorsal ligaments.

Medial ligament. It forms a short thick band which connects the tuberosity of the navicular bone with the medial aspect of the medial cuneiform bone. Superiorly and inferiorly it is blended with the dorsal and plantar ligaments respectively.

CUNEOCUBOID AND THE INTERCUNEIFORM JOINTS. The articulation of the three cuneiform bones and the lateral cuneiform bone with the cuboid are synovial articulations of plain type and the joint cavities are continuous with one another and with the cuneonavicular joint. The ligaments of the joints are the dorsal, plantar and interosseous.

Dorsal and plantar ligaments. Each consists of three bands, one connec the medial and the intermediate cuneiform bones, the second connects the inte mediate and the lateral cuneiform and the cuboid bones, and the third connec the lateral cuneiform and the cuboid bones together on the dorsal and planta aspects respectively.

Interosseous ligaments. They are three in number and connect the adj cent non-articular portions of the cuneiform and the cuboid bones.

Movements. Movements are restricted in these joints and only slight glidin movements take place in them.

TARSO-METATARSAL JOINTS

The tarso-metatarsal joints consist of articulations between the cuneiform bones and the cuboid posteriorly and the five metatarsal bones anteriorly. The line of articulation between the tarsus and the metatarsus forms an oblique line which slopes lateralwards and backwards from the medial side and consequently the medial end of the line is about three-fourths of an inch anterior to its lateral end The medial cuneiform bone articulates with the first metatarsal, the second cuneiform with the second metatarsal, the third cuneiform with the thrid metatarsal and the cuboid articulates with the fourth and the fifth metatarsal bones. In between the tarsal and the metatarsal bones there are three distinct joiot cavities, one between the medial cuneiform and the first metatarsal, one between the intermediate and lateral cuneiform bones and the second and the third metatarsal bones and the third between the cuboid and the fourth and the fifth metatarsal bones. The ligaments of the joints are dorsal, plantar and interosseous.

Dorsal ligament. The dorsal ligament of the first metatarsal and the medial cuneiform bone forms a part of the capsular ligament of the same joint. The second metatarsal bone is connected with the three cuneiform bones by three bands of dorsal ligament. The dorsal ligament for the third metatarsal bone extends from the lateral cuneiform bone. The dorsal ligament for the fourth metatarsal consists of two bands, one from the lateral cuneiform and one from the cuboid. The dorsal ligament for the fifth metatarsal extends from the cuboid bone.

Plantar ligaments. They are less regular than the dorsal ligaments and consist of both oblique and longitudinal bands. One longitudinal band connects the medial cuneiform bone with the first metatarsal and forms a part of the capsular ligament of the same joint. One oblique band connects the medial cuneiform with the second and the third metatarsal booes and another oblique band connects the fourth and the fifth metatarsal with the cuboid

Interosseous ligaments. They are three in number, medial, lateral and intermediate. The medial band is the strongest of all and connects the lateral aspect of the medial cuneiform bone with the medial aspect of the second metatarsal bone. The lateral band extends from the third cuneiform bone to the lateral side of the base of the third metatarsal bone.

Movements. Slight degree of flexion and extension are permitted in these joints specially in the articulation of the first and the fourth and the fifth metatarsals. The second metatarsal is almost immovable.

INTERMETATARSAL JOINTS. The base of the first metatarsal is not connected with the second but all the remaining four metatarsals are connected to one another by dorsal, plantar and interosseous ligaments.

METATARSOPHALANGEAL JOINTS

The metatarsophalangeal joints are condyloid type of joints and the rounded heads of the metatarsals articulate with the cup-shaped bases of the proximal pha-

nges of the toes. Each metatarsophalangeal joint has three ligaments, one capsular nd two collateral.

The **capsular ligament** blends with the deep transverse ligament of the foot n the plantar aspect. The dorsal part of the capsular ligament is very thin and blends with the extensor tendons. The collateral ligaments connect the sides of the head of the metatarsal bone with the sides of the base of the proximal phalanx.

The movements in these joints are moderate degree of flexion and extension.

INTERPHALANGEAL JOINTS. These joints have the same type of ligaments like the metatarsophalangeal joints and have the same kind of movements.

The arches of the foot

The bones of the foot articulate with each other in such a way that they form short and long arches which are well-adapted *to support the weight of the body* and at the same time they *act as "lever" to propel the body forward during walking*. They (arches of the foot) consist of longitudinal and transverse arches.

Longitudinal arch. It consists of inner and outer portions resting on a common pillar posteriorly—the tuberosity of the calcaneum. The inner part of the longitudinal arch is formed by posterior calcaneal tuberosity, the talus, the navicular, the three cuneiform bones and the first, second and the third metatarsal bones with the corresponding phalanges. The outer part of the longitudinal arch is formed by the posterior calcaneal tuberosity, cuboid and the fourth and fifth metatarsal bones with the corresponding phalanges.

The talus is the keystone of the arch. It receives the body weight and transmits t to the arches below.

The outer part of the longitudinal arch is very low and almost rests on the round. The inner part is high and only touches the ground at two points—the uberosity of the calcaneum behind and the head of the first metatarsal bone in front. The inner border of the foot is usually straight or concave inwards when weight is being borne. When the arch collapses, as it occurs in the flat-foot, this concavity becomes a convexity because the head of the talus projects down into it.

Transverse arches. The tarsal and metatarsal bones are arranged in such a way that in the articulated foot they form a dorsal convex surface and a plantar concave surface. There is normally a series of transverse arches extending from the arch formed by the heads of the metatarsal bones back to the arch formed by the navicular and the cuboid bones. In the flat-foot this arch also drops and the foot is flattened.

The structures that maintain the arch of the foot. The arch of the foot is maintained the following structures:

(1) *Muscles*—
 (a) Peroneus longus.
 (b) Tibialis posterior.
 (c) Short muscles of the foot, i.e. Abductor hallucis and digiti minimi; Flexor hallucis brevis; Adductor hallucis; Flexor digitorum brevis; Flexor digitorum accessorius.

(2) *Ligaments*—
 (a) Long and short plantar ligaments.
 (b) Spring ligament or plantar calcaneo-navicular ligament.
 (c) Transverse ligament of the heads of the metatarsal bones.

(3) *Fascia*—
 Plantar aponeurosis.

(4) *Bones*—
 The bones of the foot are mutually adapted to help in maintaining the arches of the foot.

The foot in locomotion. While *standing erect* the whole weight of the body is equally distributed to both the lower limbs and is transmitted to the ground through the feet. The foot that makes contact with the ground touches it at the heel posteriorly, at the balls of the foot anteriorly and along the lateral border. It has been observed that about half the weight is transmitted by the heel and half by the fore-part of the foot. In the fore-part of the foot the weight is distributed amongst the balls of the toes in the proportion of *2:1:1:1:1 from medial to the lateral side.* Thus it appears that about $\frac{1}{3}$ of the weight transmitted to the fore-part of the foot is borne by the ball of the great toe.

While *in locomotion*, as in walking, the weight of the body is borne alternately by the two lower limbs. While one limb is on the ground the other limb is off the ground and *swings forwards* with *dorsi-flexion at the ankle* and *flexion at the knee* and hip; associated with this there is forward propulsion of the body and the foot is now ready to receive the weight of the body in advanced position.

The foot, which is to receive the weight, is dorsi-flexed at the ankle and receives the weight by the heel or by the hinder end of the arch of the foot and then transfers it to the fore-part of the foot or the arch by plantar-flexion at the ankle joint; the gastroenemius and the soleus together with the long flexors of foot contract vigourously, there is further plantar-flexion at the ankle and the heel is raised from the ground and the weight is transferred to the fore-part of the foot through lever-action. Concurrently with the above the limb is extended both at the knee as well as in the hip joint and then the whole process is repeated.

Associated with the above changes, while the foot is on the ground, there is some flattening of the longitudinal arches of the foot which recoil back to their original position while the foot is off the ground. With dorsi- and plantar-flexion of the ankle joint there is eversion and inversion at the mid-tarsal joint respectively.

THE MUSCULAR SYSTEM OR THE MYOLOGY

THE MUSCLE

General Consideration. The muscle or the flesh is an integral part of the body mechanics in which it is mainly concerned in causing movements, locomotion and production of body heat. It consists of several muscle fibres which are variously arranged and are grouped into several bundles, and are held together by areolar type of connective tissue so as to form an individual muscle. By the term 'muscle" we understand "Mouse-like" (L. *Mus*–Mouse) and the term is so applied because some muscles resemble a mouse in gross appearance, and the tail of the mouse presumably corresponds with the tendon of the muscle.

Classification of Muscles. Muscles can be classified variously but I think that the following classification would meet the needs of most of the students.

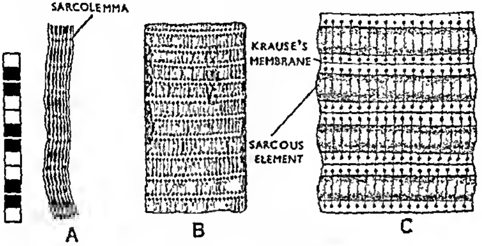

Fig. 473 & 474. Structure of striated muscle.

(1) **According to structure.**

(*a*) *Striated.* These muscles consist of fibres which are "cross striated", that is, they are both longitudinally and transversely striated. The transverse striations are well marked and consist of alternate dark and light bands (see muscular tissue). Functionally they are voluntary muscles, that is, their actions can be controlled by will.

(*b*) *Non-striated.* These muscles consist of fibres which do not present alternate dark and light striations. Functionally they are involuntary-muscles, that is, their actions are not controlled by will.

EXCEPTIONS. (i) The diaphragm muscle is structurally a striated muscle, and as such, its actions should have been voluntary, but, though its actions may be temporarily controlled, as by holding the breath, it usually works involuntarily.

(ii) The muscle fibres of the pharynx and the upper part of the oesophagus are striated but they are involuntary in action, that is, their actions are not controlled by will

(iii) The ciliary muscle of the eye is structurally a non-striated muscle, but, although it acts involuntarily to a great extent, its action can voluntarily be controlled to some extent during forced accommodation.

(*c*) *Cardiac muscle.* Structurally the cardiac muscle is a special variety of muscular tissue which is intermediate between striated and non-striated muscle (see muscular tissue, cardiac muscle). It is an automatic organ

which contracts rhythmically and is not under the control of will, hence an involuntary muscle.

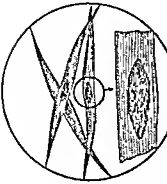

Fig. 475. Involuntary muscle fibre.

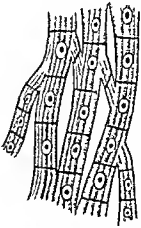

Fig. 476. Structure of cardiac muscle.

(2) **According to whether their actions are under the control of will or not.**

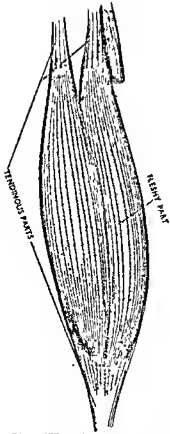

Fig. 477. The biceps brachii muscle showing the parts of a voluntary muscle.

(*a*) *Voluntary*. All voluntary muscles are striated muscles and their actions are under the control of will or volitional power.

(*b*) *Involuntary*. All involuntary muscles are non-striated structurally and their actions are not under the control of will (see Exceptions—already referred to).

(3) **According to development.**

(*a*) *Somatic*. All somatic muscles develop in relation to the body wall developmentally and are derived from the somatopleuric mesoderm. They are striated muscles and are mainly concerned to adapt the human body to its external environment and form the chief source of heat and energy.

(*b*) *Visceral*. They develop in relation to the different viscera and are derived from the splanchnopleuric mesoderm. They are non-striated or plain muscles and are mainly distributed in the walls of the hollow viscera namely stomach, intestines, gall bladder, urinary bladder, blood vessels, etc.

VOLUNTARY OR SOMATIC MUSCLE

Parts of a voluntary muscle. Usually a voluntary muscle consists of a *fleshy* and a *fibrous* part with the exception of a few which are all through fleshy. A voluntary muscle usually stretches between two points across a joint and its attachment proximal to the joint in which its actions mainly concentrate, is known as its *origin* while its attachment distal to the joint is known as its *insertion*. The fibres of origin may be fleshy or tendinous (fibrous) which are called the *fleshy belly* or *head* and

the *tendinous head* respectively. The fibres of insertion are usually tendinous and when they are condensed to form a cord-like structure it is called a *tendon*, and when broad and membranous, it is called an *aponeurosis*.

Difference between the fleshy and the tendinous parts of a Muscle:

FLESHY PARTS	TENDINOUS PARTS
(1) They are highly specialised, contractile, vascular, expensive in upkeep and usually resistant to infection because of abundant blood supply.	(1) They are not specialised, inelastic, relatively avascular and inexpensive in upkeep. They are less resistant to infection because of the absence of sufficient blood vessels.
(2) Yield to pressure easily and are less strong.	(2) Do not yield to pressure easily and immensely strong. A tendon of 1" square is capable of supporting a weight from 9700 to 18000 lbs.
(3) Prolonged disuse causes atrophy (wasting).	(3) Disuse atrophy is absent.
(4) When they contract they shorten between $\frac{1}{3}$ and $\frac{1}{2}$ of their resting length and swell accordingly.	(4) Do not contract and there is no change when the muscle contracts.

Gross structure of a voluntary or somatic muscle. A muscle is composed of muscle fibres which are held together by a membranous investment from the areolar tissue in a definite pattern. An individual muscle fibre is surrounded by a delicate layer of loose areolar tissue known as the *endomysium*. A group of muscle fibres is arranged into a bundle to form an individual *muscular fasciculus* which is surrounded by another denser layer of areolar membrane known as the *perimysium*. Ultimately the muscular fasciculi are bound and ensheathed together to form the individual muscle by an investing areolar membrane known as the *epimysium*. The epimysium becomes thickened to intervene between two muscles or between two groups of muscles to form the *intermuscular septum*.

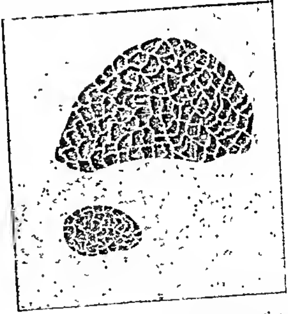

Fig. 478. The figure above is a transversesection of a muscle showing muscular fasciculi. The figure below is a transverse section of an individual muscle fibre with its surrounding endomysium.

Nomenclature of voluntary muscles. Muscles are named as follows:—

(1) *According to some geometrical shapes.* Triangularis, trapezius, rhomboideus, quadratus lumborum etc.

(2) *According to general form.* Longus capitis, serratus anterior, latissimus dorsi, etc.

(3) *According to heads of origin.* Biceps, triceps, quadriceps, diagastric etc.

(4) *According to structure.* Semimembranosus, Semitendinosus.

(5) *According to location.* Temporalis, supraspinatus, intercostalis etc.

(6) *According to attachments.* Stylo-hyoideus, ilio-costo-cervicalis, cricotbyroideus etc.

(7) *According to direction of fibres.* Rectus abdominis, obliquus externus abdominis, etc.

(8) *According to contrasting features.* Pectoralis major and pectoralis minor, teres major and minor, gluteus maximus and minimus etc.

(9) *According to functions* (i) *Flexors.* Muscles concerned in causing flexion or bending of a particular joint are known as flexors.

(ii) *Extensors.* Muscles that cause the opposite movement of the flexors are known as extensors.

(iii) *Adductors.* Muscles which by their action carry a particular limb towards the median plane are known as adductors.

(iv) *Abductors.* Muscles which by their action carry a particular limb away from the median plane are known as abductors.

(v) *Pronators.* These muscles are found only in the forearm and they, by their action, cause the forearm and the palm of the hand to be carried backwards as in giving something to somebody.

(vi) *Supinators.* These muscles cause opposite movement of the pronators, as in taking something in the palm of the hand.

Besides the above classification which includes majority of the muscles, there are some other muscles which have special function to do in particular parts of the body and are named according to their functions, as for example *compressors, dilators, depressors, elevators, invertors, evertors, constrictors* etc.

PHYSICAL PATTERNS OF MUSCLES.

(*a*) STRAP OR FUSIFORM MUSCLES. It has already been stated that a muscle is composed of a group of muscular fasciculi which may be disposed either longitudinally along the long axis of a muscle or they may be disposed obliquely or transversely; depending on the nature of distribution of the muscular fasciculi within a muscle, some types of muscular pattern are formed which have distinctive functional significance. Thus when the fasciculi are disposed longitudinally between two points of attachments, the muscle is called a *strap* or a *fusiform muscle.*

(*b*) PENNATE MUSCLE. When the fasciculi are arranged obliquely in relation to the long axis of a muscle, that is, when they are attached obliquely to the tendon of insertion like the "berb of a feather" the resulting muscle is a *pennate muscle.* The pennate muscles are further subdivided as follows:—

(i) *Unipennate.* If the oblique fasciculi are attached to only one side of the tendon of insertion it is called an *unipennate muscle* (palmar interossei).

(ii) *Bipennate.* When the oblique fasciculi are attached to both the sides of the tendon it is called a *bipennate muscle* (tibialis posterior).

(iii) *Multipennate.* When there are a series of tendinous bands within a muscle and the muscular fasciculi are arranged like the bipennate muscle it is called a *multipennate muscle* (Deltoid).

(iv) *Circumpennate.* When the fibres of a muscle converge on a tendon from all the sides, the latter (tendon) being burried and extended within its substance, the muscle is said to be a circumpennate one, as for example, the tibialis anterior muscle.

Importance of fascicular groupings and muscle force. By fascicular groupings the actions of the muscles are concentrated to the tendon of insertion (by which precision in movement is amply secured) and by this arrangement both the range of movement and the force of contraction are guided properly.

In a fusiform type of muscle the muscular fasciculi are much longer in comparison to the oblique fasciculi of the pennate muscles. It is known that the length

of the muscular fasciculi of a muscle and its range of movement are closely interrelated. It has been shown by experiments that the muscle fibres, when fully stretched in relaxation, can contract upto a little over fifty per cent of their own length. Thus a muscle, whose fasciculi are four inches long, can contract more than two inches causing the same length of displacement of the structure to which it is attached. *Therefore the range of movement of a muscle is proportional to the length of its fibres of which*

Range of movement ∝ length of fibres

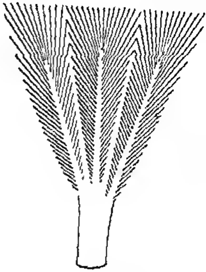

Fig. 479. Shows fascicular arrangements in an unipennate muscle.

Fig. 480. Shows fascicular arrangements in a bipennate muscle

Fig. 481. Shows fascicular arrangements in a multipennate muscle.

it is composed. Thus it is expected that a joint, which has to undergo a wide excursion to complete its movement, is controlled by muscles with long fasciculi. Full flexion of the elbow joint from the position of extension involves a considerable range of movement and therefore the muscles concerned in this movement, that is, the biceps and the brachialis, are provided with long fasciculi which are disposed longitudinally.

Similarly, taken for granted that all muscle fibres are of equal thickness, *the force of contraction of a muscle (muscle force) is proportional to the number of fibres it contains, the more the number the more is the force of contraction.* We know that the pennate muscles are composed of numerous short, oblique fasciculi and therefore it is expected that their range of movement would be minimum, but the number of fibres being numerous, their force of contraction would be much greater. By the organisation of short, oblique fasciculi in the penniform muscles, they have been provided with more fibres, because in a compact space more fibres can be housed if they are arranged in short, oblique fasciculi than the longitudinal ones. These muscles are situated in those places where by short range of movement considerable force has to be exercised, as for example, the tibialis posterior (a bipennate muscle), which has to raise the whole weight of the body in plantar-flexion of the ankle joint during walking, exerts a great force in a short range of movement.

Active and Passive insufficiency of muscles. When a muscle contracts it can shorten up to a certain limit beyond which any attempt to cause further shortening is associated with pain. Similarly, a muscle can be stretched or elongated passively upto a certain limit beyond which further stretching is impossible due to tension of the inextensible collagenous fibres within the muscle. In a joint-movement when a muscle or a group of muscles reaches its stage of limitation either in contraction or in lengthening, further movement in the joint is restricted which

might otherwise occur, and such muscles under the above condition are said to be *insufficient*. As mentioned above insufficiency may be either active or passive.

Active insufficiency. During active contraction in a particular joint-movement a muscle may be insufficient to effect full range of movement and is said to be actively insufficient. For example, when the thigh is extended at the hip the hamstring muscles by their contraction fail to produce full flexion of the knee joint.

Passive insufficiency. During a particular joint-movement passive stretching of a muscle or a group of muscles may occur up to a certain limit beyond which it fails to lengthen further thereby causing restriction of the joint-movement. For example, when the thigh is flexed at the hip, extension of the knee beyond a certain limit becomes impossible due to tension of the hamstrings.

The limits of passive insufficiency may vary in health and disease. It is much modified in case of the acrobats whereas in some diseases of the central nervous system it is more restricted.

Hypersufficient. Even after the extreme position of a joint in a particular movement has been reached, if the muscle causing the same movement has the power to contract still further the muscle is said to be *hypersufficient*. As for example, the triceps is a hypersufficient muscle. Its range of contraction is more than what is necessary to cause full extension of the elbow and it is prevented from reaching its maximum limit of contraction by the bony locking between the olecranon process of the ulna and the olecranon fossa of the humerus. This is a measure in which the triceps is allowed to make the elbow joint effectively rigid, so that, the arm and the forearm can work as a single unit whenever necessary.

Functional Grouping. According to distribution of work in a particular movement in a particular joint, muscles are grouped functionally as follows:—

Prime movers. In a particular movement it has been observed that some muscles are principally involved and act directly on their point of insertion and are obviously *responsible for causing the particular movement* while others assist in the process either directly or indirectly. The muscles, which act directly on their point of insertion and are mainly responsible for a particular movement, are called *Prime movers*.

Synergists. When the combined action of a group of muscles produces a particular movement, which may be different from that produced by any member of the group acting individually, the muscles producing the particular movement are called *synergists*. As for example, the flexor carpi ulnaris and flexor carpi radialis by their combined action produce the flexion of the wrist joint but acting individually the former is an adductor and the latter is an abductor of the wrist joint.

Some anatomists believe that the synergists help the prime movers by preventing the unwanted movements inherent in the attachment of the prime movers and help by fixing the joint other than the one on which the prime movers work. This allows the term "synergists" to have flexible meaning and there is scope for confusion about the terms "antagonists" and "fixators". The muscles which are mainly concerned in stabilising or fixing the bones involved in a particular joint-movement should better be called "*fixators*".

Antagonist. The muscles which act reversely to that of the prime movers are called *antagonists*. Whereas the prime movers actively contract to effect a movement the antagonists show either active relaxation or contract to produce traction in a reverse direction (reverse to that of the prime movers) so that the particular movement becomes smooth and orderly. As for example, flexion or bending of the elbow is caused by contraction of the brachialis and the biceps brachii (prime movers), and during flexion, the triceps brachii acts antagonistically by showing active relaxation. Similarly, in the abduction of the shoulder (carrying the arm away from the trunk) the deltoid and the supraspinatus are prime movers which act in close association with each other. The subscapularis, infraspinatus and the teres minor are antagonists and act reversely to that of deltoid. In the initial stage of the move-

ment the deltoid tends to displace the head of the humerus upwards and the antagonists such as the subscapularis, teres minor and the infraspinatus by acting reversely tend to pull down the head of the humerus preventing its displacement upwards and thus the movement of abduction of the shoulder becomes smooth and orderly.

It is a curious phenomenon to note, that in a particular movement, some muscles actively contract while others actively relax at the same time, so as to give effect to a particular movement. This can be explained by the fact that *in the brain it is the particular movement which is represented and not the action of a particular muscle* and the brain executes the performance of any particular movement through the system of *reciprocal innervation of muscles.* In reciprocal innervation, motor impulses from the brain which cause contraction of one group of muscles in a particular movement, exerts reverse type of action to the antagonistic members in the same movements. As for example, in flexion of the elbow, the area of the brain governing this particular movement exerts dual influences, in one hand causing the flexors of the elbow to contract actively and on the other hand causing the extensors of the elbow to relax actively, thereby, the movement of flexion becomes smooth and orderly.

How a muscle acts. The prime action of the muscles is to contract by virtue of which they impart lever-action to the bones and thereby they create *movement by contraction* through the medium of joints. Besides the power of contraction, muscles can also act by showing *active relaxation,* as for example, in flexion of the elbow joint the triceps brachii shows active relaxation so as to make the movement smooth and orderly.

Besides showing active contraction and relaxation, a muscle can also act by simply increasing the tone of its muscle fibres without any contraction or shortening. The condition in which the muscle fibres act by simply increasing their tone without showing any apparent shortening is known as the *isometric contraction of muscle.* While maintaining erect posture the quadriceps femoris keeps the knee extended by isometric contraction, that is, the tone of its muscle fibres is increased, the length of the fibres remaining constant. The reverse type of action is the *isotonic contraction* in which the tone of the muscle fibres remains constant but the length of the fibres is shortened as is seen in case of usual contraction of any muscle.

In resting condition, the muscles neither contract nor they show active relaxation but they *remain in a state of sustained minimal contraction or tension* and this action of the muscles is known as *tonicity of muscle or muscle tone.* The muscle tone is dependent on the integrity of the reflex arc and may be lost if the nerve supplying the muscle is damaged. Moreover, in some diseases of the central nervous system the muscle tone may be either exaggerated or abolished.

During average work not all the muscle fibres are thrown into action, but when they are to work against stiff resistance, all of them are thrown into action. Moreover, when a muscle is to work continuously, in order to avoid fatigue, muscle fibres work in shifts. When all the muscle fibres are made to work, as against resistance, it is called the *reinforcement of muscular action.*

A muscle is said to be active when its muscle fibres shorten due to contraction but it may be active as well while actually lengthening. As for example, in extension of the elbow under resistance, the biceps brachii, which is a flexor of the elbow work efficiently to lengthen gradually "to pay out" the extensor of the elbow, that is, the triceps brachii to make the movement smooth and orderly. This type of active lengthening of a muscle is called *excentric action* in contrast to *concentric action* in which the muscle fibres actually shorten as in usual contraction of a muscle.

Co-ordination of muscular movements. GROUP ACTION OF MUSCLES. When a particular muscle works alone in its individual capacity it is seen to produce a movement which is different from what is seen when it works in a group with some other muscles. As for example, when the flexor and extensor carpi ulnaris work together they cause adduction of the wrist, when any of them works alone it produces an oblique movement different from that of adduction; further when the flexor carpi ulnaris works together with palmaris longus and flexor carpi radialis it is seen to produce flexion of the wrist joint. This joint-effort movement

which is different from that produced by their individual effort is known as *group action of muscles*. In a joint, to produce a particular movement, many a muscle combine together to produce that particular movement, although, their indiviuual action may differ from that produced by their combined effort. Thus the co-ordinated actions of prime movers, synergists and antagonists in producing a particular movement are group actions.

In the lower limb, muscles are more accustomed to work together than those in the upper limb, where, for reasons of precision and delicacy in the performance of some movements, muscles acquire wide range of individualism. In other words, an individual muscle in the upper limb has got more to do in a particular movement and it is less dependent on its helping members whereas in the lower limb an individual muscle can produce very little effect without the assistance from its helping members, that is, group action of muscles is a dominant feature in the lower limb. Advantage of this anatomical fact is duly taken in transplantation of muscle in case of paralysis of any member of the same in the upper limb where due to acquired individualism an extensor muscle can be transplanted in the place of a paralysed flexor and can be trained to take up the functions of the latter and vice versa. For the above reasons transplantation of muscle in the lower limb often fails to bring back the functional integrity because the muscles of the lower limb are accustomed to work in groups and they acquire little or no individualism.

ASSOCIATED ACTION OF MUSCLES. In some particular movements, in addition to the muscles concerned in causing the same movement, some remote group of muscles which are not at all concerned in that particular movement, are also called into actions in association with the former group of muscles and such co-ordination of action of muscles is known as *associated action of muscles*. As for example, when the head is turned to one side both the eye balls also move to the same direction.

POSTURAL ACTION OF MUSCLES. In order to maintain normal posture of the body some muscles are constantly at work against gravity (antigravity action) which tends to break down the posture assumed by the individual. As for example, when we stand erect, gravity acting on the forepart of the trunk, tends to make it kyphotic but the extensors of the back by having gained in increased tone act against the gravity (antigravity muscles) and maintain the erect posture, such action of muscles in maintaining the posture of the body is called the *postural action of muscles*.

Other aspects of muscular action. DUAL ACTION OF MUSCLE. Some muscles are found to have dual roles in their functional capacity, that is, some muscle may function as a voluntary as well as an involuntary muscle. As for example, when the lattisimus dorsi, which is a voluntary muscle, is paralysed it ceases to function voluntarily but it still functions involuntarily in conjunction with its healthy counterpart on the opposite side during sneezing, coughing, etc. Such dual roles played by a muscle are known as *dual action of muscle*.

LIGAMENTOUS ACTION OF MUSCLES. Ligaments are tough, rigid, and inelastic structures which restrain undue mobility of a joint. Some of the muscles (antagonists) acquire ligamentous function by preventing undue mobility in a joint during varying joint-positions. Moreover, by this action they spare the inelastic ligaments from being overstretched and thus having accessory ligamentous action.

Paradoxical action of muscles. Gravity aids some movements as in sitting from standing position. In this condition the hamstrings which are flexors of the knee, are to work very little, if at all. Here the gravity of the weight of the trunk is the cause; flexion of the knee and the hip is the effect, and the quadriceps femoris and the extensors of the hip are the effectors, that is, while in contraction during the said movement they show controlled gradual relaxation, "paying out the rope", so as to effect the movement. Here the quadriceps femoris, which is an extensor of the knee, is acting as the *flexor*. This reversal of action of the quadriceps while it is to work against gravity is known as its *action of paradox*.

Development of striated muscles. The somatic or the striated muscles develop from two sources. Those of the head and neck are derived from the mesoderm of the pharyngeal arches while most of the other (somatic) muscles are derived from the *myotomes.*

MUSCLES OF THE HEAD AND NECK. The muscles of the head and neck are derived from the mesoderm of the pharyngeal arches. For the group of muscles that arise from the individual arch see pharyngeal arches.

MUSCLES OF THE TRUNK AND LIMBS. Although opinion differs as to the sources of the muscles of the limbs it may be deduced from the nature of the segmental innervation of the muscles that these muscles arise from the myotomes which receive segmental innervation.

The paraxial mesoderm during early part of development is segmented into different rectangular blocks and form about 35 to 40 such blocks at the end of the fifth week. Each block receives its segmental nerve and is separated from its fellow by an intervening connective tissue known as the *myoseptum.* Soon after each block can be divisible into three portions, the medial, the lateral and the intermediate portions. The medial portion gives rise to the formation of the vertebral column and is known as the *sclerotome*; the lateral portion gives rise to the formation of the skin and its appendages and is known as the *dermatome*; the intermediate portion is the *myotome.* The myotomes with their respective segmental nerves move away from their original positions either as a whole or in part or several of them may be fused together and give rise to the formation of different muscles by transformation of the cells of the myotome into muscular tissue. As the myotomes carry their individual segmental nerves, the muscles formed by the fusion of several myotomes are supplied by more than one nerve and such muscles which are supplied by more than one nerve are called *compound* or *hybrid muscles* because they are formed by combination of more than one myotome.

TRANSFORMATION OF MYOTOME INTO MUSCULAR TISSUE. Myotomes which are formed by mesodermal condensation consist of fusiform cells which are called *myoblasts* and contain a single nucleus. The nucleus soon divides by a mitotic division and the myoblasts become elongated and multi-nucleated. Later on granules appear in the cytoplasm and the cells become transversely striated along their peripheral parts. The granules arrange themselves in rows which run together and form the myofribillae. The nuclei of the cells at this stage occupy a central position whereas the myofibrillae are disposed peripherally. Subsequently the myofibrillae multiply rapidly by longitudinal divisions and spread out centrally and as a result, *the nuclei which were centrally placed, are displaced peripherally so as to occupy* the subsarcolemmal position, a position which they normally occupy in a fully grown muscle fibre.

The development of tendon of a muscle has been described on pages 477 & 478.

Vascular supply of striated muscle. The striated muscles get their nourishment from muscular branches of the adjacent artery. These muscular branches accompany the motor nerve of the muscle and break out into capillary bed which run along the muscle fibres. Some of the blood vessels enter the muscle independent of the motor nerve and these are called *accessory blood vessels.* Veins which drain the muscle usually accompany the artery and are accompanied by the lymphatics.

Nerve supply of the striated muscle. The nerve supplying a muscle is popularly known as the motor nerve but in reality *it is a mixed nerve* and contains about 3/5 motor and 2/5 sensory filaments and in addition, it also contains some sympathetic filaments. The motor and sensory filaments are respectively called *efferent* and *afferent fibres.*

The *efferent* or *true motor fibres* are medullated which end in the *motor end-plates* of the muscles. The motor end-plate is a specialised area of granular cytoplasm within the muscle fibre where the motor nerve filaments end by dividing into finger-

like branches with some undifferentiated tissue in between. Just before entering into the muscle fibre the nerve filament loses its myelin sheath whereas its neurilemma sheath becomes continuous with the sarcolemma of the muscle fibre. The sarcoplasm in the end-plate area is more granular and shows concentration of the nuclei of the muscle fibre. Functionally the motor fibres are responsible for tonicity and contractility of the muscle.

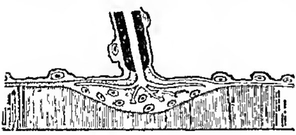

Fig. 482. The motor end-plate in a muscle.

The *sensory* or *afferent nerves fibres* are also medullated fibres which originate within the muscle and are found in three forms. Some begin as *free ends* within the muscle fibre, some as *encapsulated ends* in the connective tissue in between the muscle fibres and some as *muscle spindles* (see nervous tissue). Functionally the sensory or afferent nerve of a muscle is responsible for carrying different sensations from the muscles and the muscle sense. They are also necessary for maintaining tone of the muscles.

SYMPATHETIC NERVES. These are non-medullated or finely medullated fibres derived from the sympathetic component of the autonomic nervous systemsand are distributed to the plain muscles of the blood vessels of the muscle (Vaso-motor fibres). They are also distributed to the muscle fibres and are believed to be concerned in the trophic function of the muscle.

Motor unit of a muscle. A motor neurone which consists of a nerve cell with its processes, controls about 100 muscle fibres and this single neurone together with the muscle fibres it controls (100) is known as the *motor unit of a muscle*. During resting period only a few motor units come into play but while the muscle is in active contraction majority of the motor units are thrown into action.

Motor point of a muscle. The nerve supplying a muscle enters into it at or about its centre and the point of its entrance is known as the *motor point* of a muscle. The motor point of a muscle is more or less constant and in experimental physiology, in order to estimate the electrical responses, the electrode is fixed on the skin overlying the motor point of the muscle. The entrance of the nerve through the motor point has some positional advantage due to which it is spared from any disturbance during muscular action.

Repair and regeneration of muscles. When muscles are grossly damaged the muscle fibres lose their regenerative power and repair takes place by proliferation of the fibrolastic tissues. When individual muscle fibre is damaged or the damage is localised to a very small area regeneration of muscle fibres with full return of functions may take place. From the remnants of the damaged muscle fibres protoplasmic buds come out and soon these undifferentiated buds acquire cross striations and subsequently develop into muscle fibres. It is believed that after partial damage the muscle fibre differentiates into myoblast and subsequently into a muscle fibre.

Red and white muscles. A striated muscle consists of "red" and "white" fibres and they are called red and white muscle respectively. The colour of red fibres is due to the presence of a pigment called myo-haemoglobin which is concerned in transferring oxygen from the blood to the contractile elements of the muscle fibres. The red fibres contain more fat in their sarcoplasm than the white fibres. The red fibres contract slowly and their contractions remain more sustained and therefore they are suitable for maintaining posture. The white fibres contract quickly and their contractions remain less sustained.

The Tendon and its Sheath. Tendons are cord-like structures which form the fibrous link between the muscle and the bone or the other structure to which the

muscle is attached. Tendons usually form the basis of either origin or insertion or both of some muscles and occupy either one or the other end or both ends of the fleshy belly of a muscle. Digatric muscle on the neck is an exception to this and is fleshy at both ends but is tendinous in its intermediate position. This irregular formation of intermediate tendon has been explained by the fact that the two fleshy bellies (anterior and posterior) have two different sources of origin in embryonic life, the anterior belly being derived from the myotome of the mandibular arch whereas the posterior belly from the myotome of the hyoid arch and the position of intermediate tendon corresponds to the myoseptum between the two. Tendinous intersections within the fleshy belly of some muscle such as rectus abdominis, also represent the persistance of the intersegmental myosepta.

Development. Tendons develop in association with the muscle from the same source, that is, the undifferentiated mesenchymal cells. While mesenchymal cells differentiate into myoblasts and subsequently into muscle fibres, the latter exerts tensile force on the still undifferentiated mesenchymal cells and as a result the mesenchymal cells differentiate into fibroblast. The fibroblasts lay down collagen fibres in the direction of the muscular pull and thereby resulting in the formation of the tendon which is lined by a layer of connective tissue.

Sheaths are also found to be formed around some tendons and are specially designed to subserve protective and nutritive functions to the tendons; they also add leverage to the actions of the muscles. Prior to the formation of the tendon mesenchymal cells arrange themselves circularly in the region of the future tendon formation and later on they tend to separate from one another and as the mesenchymal cells are in syncytial connections with one another by their protoplasmic processes, the process of separation leads to the formation of a circular investment with a cavity within, which is lined by a layer of flattened mesothelial cells. Later on fibroblasts formed by differentiation of the mesenchymal cells, lay down collagen fibres and a loose connective tissue investment is formed around the tendon. The tendon itself is also lined by a layer of flattened mesothelium which is continuous with the mesothelium lining the connective tissue investment and thus a parietal and a visceral layer of connective tissue investment with a lining of flattened mesothelial cells are formed containing a potential space between the two layers. The potential space usually contains a glairy mucinous fluid which provides nutrition to the tendon as well as protects the tendon from being subjected to pressure and friction from the surrounding structures.

It is also known that fleshy belly of a muscle when subjected to pressure and friction undergoes tendinous changes.

Histological structure of a tendon. The tendon of a muscle is essentially a fibrous structure and consists of parallel bundles of collagen fibres and a single layer of fibroblast which intervenes between the collagen bundles.

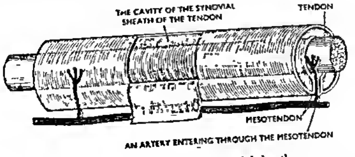

Fig. 483. A tendon with its synovial sheath.

Nutrition of tendons. All fibrous tissues are of low metabolic activity and consequently they require minimum of vital fluid for their upkeep and nutrition. Ordinarily a tendon gets its nutrition from two sources, one from the blood vessels

of the fleshy belly and the other from the blood vessels of the periosteum to which it is attached. Minute blood vessels from both the sources pass through the space between the collagen bundles and anastomose with one another within the tendon and provide nutrition for it. In cases where the tendon is too long, as in cases of the digital tendons of the hand, in addition to the above mode of nutrition the tendon gets its nutrition from the blood vessels reaching the tendon through the mesotendon as well as from the synovial fluid contained in the synovial sheath of the tendon.

NERVE SUPPLY OF TENDONS. *Tendons are supplied only by sensory nerves.* Sensory nerves reaching the tendon show special features in their mode of termination which are specially designed to carry two types of sensations namely proprioceptive sensation and painful sensation.

The nerves carrying proprioceptive sensations end in terminations which are adapted to from two types of end-organs namely *Golgi tendon organs and Pacinian corpuscles* (for details see nervous tissue). The Golgi tendon organ is contained

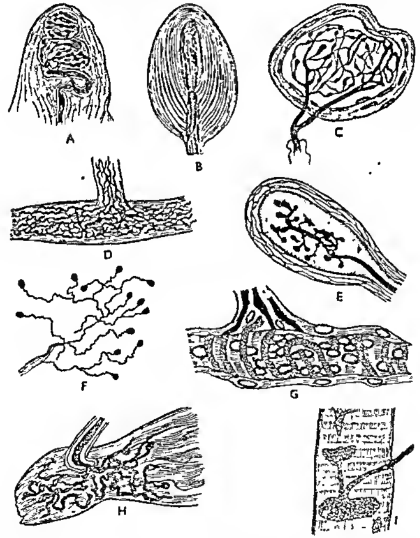

Fig. 484. A—Tactile or Meissner's corpuscle; B—Pacinian corpuscle; C—End-bulb of Krause; D—Organ of Ruffini; E—Organ of Golgi-Mazzoni; F—Free nerve terminals; G—Muscle Spindle; H—Golgi bodies (Organ of Golgi); I—End plates.

within the tendon close to the musculo-tendinous junction whereas the Pacinian corpuscles are found in walls of the tendon sheath.

The nerves carrying painful sensations form very fine ramification within the tendon and its sheath.

FUNCTIONS OF TENDONS. The fleshy belly of a muscle is too bulky in comparison to its tendon and it is a device for the muscle by which the muscular action is concentrated to its tendon which again concentrates its pull to the structure to which it is attached. It adds leverage to the muscle and allows the muscle to work from a distance. The fleshy belly of a muscle cannot endure pressure and friction, therefore in those places where the muscle is liable to be subjected to pressure and friction the tendon replaces the fleshy belly. The tendon reduces the bulk of the muscle considerably, a measure for the nature's economy, because the muscles are too expensive metabolically in their upkeep. It reduces the surface area for muscular attachment and thereby enables the muscle to exert its maximum effect to a minimum area and thus precision of effects is much improved.

THE FASCIAE AND THE MUSCLES OF THE HEAD AND NECK

THE REGION OF THE FACE

THE MUSCLES OF FACIAL EXPRESSION

The muscles of facial expression form a group of muscles, most of which are directly connected with the skin in the region of the face and scalp and are concerned in producing different types of facial expression. As these muscles are gaining attachment to the skin there is no deep fascia barrier in this region.

It may be observed that most of these muscles are connected to one another so as to leave the semblance of a single muscle-mass with different tails of attachment. The facial muscles are supplied by the facial nerve (7th cranial) and have been discussed under the following sub-heads.

(a) SUPERFICIAL MUSCLES OF THE MOUTH

- Orbicularis oris.
- Levator labii superioris.
- Zygomaticus minor.
- Zygomaticus major.
- Depressor anguli oris.
- Levator labii superioris alaeque nasi.
- Depressor labii inferioris.
- Risorius.

Orbicularis oris. It forms the sphincter for the oral aperture and the structural framework of the lips. It is a complex muscle consisting of three strata of muscles fibres, superficial, intermediate and the deep.

The superficial stratum of fibres is prolonged from the levator anguli oris, depressor anguli oris, levator labii superioris, depressor labii inferioris and zygomaticus major et minor and they extend as far as the centre of the lip where they end by being attached to the skin and are not continuous with the fellow of the opposite side. These muscles converge to the angle of the mouth where they decussate to form a nodular mass, often called the *modiolus*.

The intermediate stratum of fibres is derived from the buccinator muscle whose fibres are continuous with the fellow of the opposite side.

The deep stratum of fibres arises from the alveolar margin of the incisive fossae of the maxilla and the mandible and are called the *incisivus labii superioris* and *incisivus labii inferioris* respectively; and they blend with the main muscle mass.

Nerve supply. It is supplied by the facial nerve through its lower buccal and mandibular branches.

Action. It closes and opens the oral aperture and helps in the articulation of speech. It also causes change in shape and form of the lips.

Levator labii superioris. It arises from the infraorbital margin of the maxilla and from the antero-inferior margin of the zygomatic bone and is inserted into the orbicularis oris.

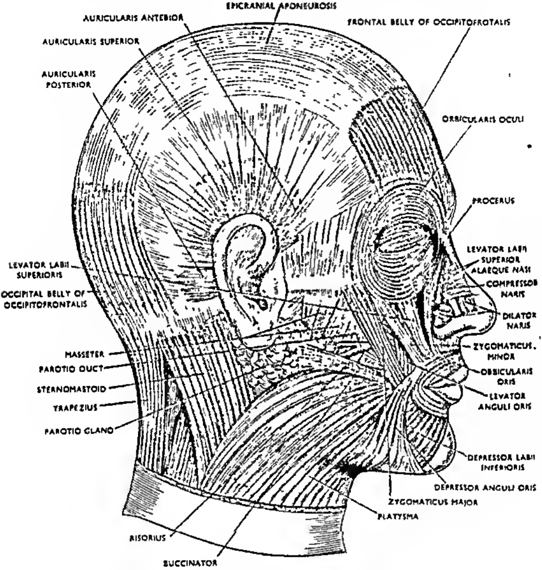

Fig. 485. The muscles of the face and scalp. Seen from the right lateral side.

Nerve supply. It is supplied by the buccal branches of the facial nerve.

Action. Together with the zyomaticus minor it produces the naso-labial fold and elevates and everts the upper lip.

Zygomaticus minor. It arises from the malar surface of the zygomatic bone in front of the zygomaticus major and passing obliquely downwards and forwards is inserted into the orbicularis oris.

Nerve Supply. It is supplied by the buccal branches of the facial nerve.

Action. Same as levator labii superioris.

Zygomaticus major. It lies behind the zygomaticus minor and extends from the zygomatic bone to the orbicularis oris.

Nerve supply. It is supplied by the buccal branches of the facial nerve.

Action. It elevates the angle of the mouth and draws it laterally as in laughing.

Depressor anguli oris. It arises from the oblique line of the mandible and is triangular in form. Its apex is inserted into the orbicularis oris at the angle of the mouth.

Nerve supply. It is supplied by the mandibular branch of the facial nerve.

Action. It depresses the angle of the mouth and draws it laterally.

Levator labii superioris alaeque nasi. It arises from the frontal process of the maxilla in front of the anterior lacrimal crest and descending downwards by the side of the nose it divides into medial and lateral slips; the medial slip is inserted into the lateral cartilage of the nose and the lateral slip to the orbicularis oris.

Nerve supply. It is supplied by the buccal branches of the facial nerve.

Action. Its medial slip dilates the anterior nasal aperture whereas its lateral slip elevates and everts the upper lip.

Depressor labii inferioris. It lies deep to depressor anguli oris and arises from the anterior part of the oblique line of the mandible and is inserted into the orbicularis oris and into the skin of the lower lip.

Nerve supply. It is supplied by the mandibular branch of the facial nerve.

Action. It depresses the lower lip and draws it laterally.

Risorius. It is a small subcutaneous muscle which takes its origin from the parotid fascia and is inserted into the skin at the angle of the mouth.

Nerve supply. It is supplied by the buccal branches of the facial nerve.

Action. It draws the angle of the mouth backwards as in grinning.

(b) Deep Muscles of the Mouth

- Levator anguli oris.
- Incisivus labii superioris.
- Incisivus labii inferioris.
- Mentalis.
- Buccinator.

Levator anguli oris. It lies deep to levator labii superioris and arises from the canine fossa of the maxilla and is inserted into the orbicularis oris opposite the angle of the mouth.

Nerve supply. It is supplied by the buccal branches of the facial nerve.

Action. It raises the angle of the mouth and produces the naso-labial fold.

Incisivus labii superioris. It is a small muscular bundle which arises from the upper alveolar margin opposite the lateral incisor or canine tooth and is inserted into the back of the orbicularis oris, near the angle of the mouth.

Nerve supply. It is supplied by the lower buccal and the mandibular branches of the facial nerve.

Action. Same as orbicularis oris.

Incisivus labii inferioris. It arises from the lower alveolar margin opposite the lateral incisor tooth and is inserted to the back of the orbicularis oris in the lower lip.

Nerve supply. It is supplied by the lower buccal and the mandibular branches of the facial nerve.

Action. Same as orbicularis oris.

Mentalis. It lies medial to and on a deeper plane than the depressor labii inferioris and arises from the fossa below the incisor teeth of the mandible and is inserted into the orbicularis oris.

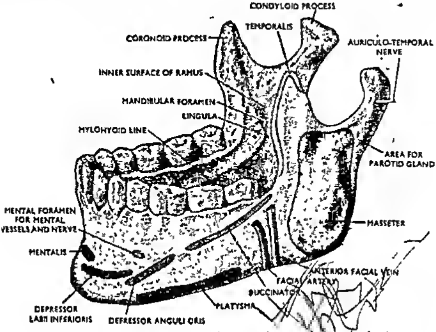

Fig. 486. The mandible showing the muscular attachments and relations. Seen from the left side.

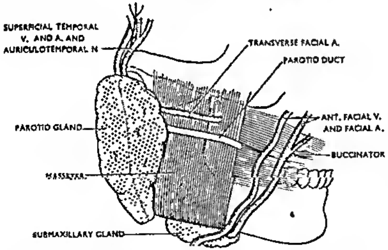

Fig. 487. Some superficial relations of the mandible. The facial muscles and branches of the facial nerve have been omitted.
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Nerve supply. It is supplied by the mandibular branch of the facial nerve.

Action. It causes wrinklings of the skin of the chin and helps in raising the lower lip.

Buccinator. It is roughly quadrilateral in shape and arises from the outer surface of the alveolar processes of the maxilla and the mandible opposite the

scapula fixed when both muscles work together the head is extended at the atlanto-occipital joint.

Posterior triangle. The posterior triangle lies behind the sternomastoid and its apex is directed upwards and the base downwards.

BOUNDARY. *Anteriorly* it is bounded by the posterior border of the sternocleidomastoid (sternomastoid) and *posteriorly* by the anterior border of the trapezius. Its *base* is formed by the middle-third of the clavicle and the *apex* by the union of the trapezius and the sternocleidomastoid muscles. Its floor is muscular and is formed by the splenius capitis, levator scapulae, scalenus medius, scalenus posterior and a portion of the first digitation of the serratus anterior from above downwards. The prevertebral layer of the deep cervical fascia covers the muscles in the floor and separates these muscles from its roof. Its *roof* is formed by the investing layer of the deep cervical fascia which bridges across the gap between the anterior border of the trapezius and the posterior border of the sternocleidomastoid.

When the anterior and posterior borders of the triangle do not meet at the apex the semispinalis capitis forms the uppermost muscle in its floor. The inferior belly of the omohyoid passes across the lower part of the triangle and subdivides it into *upper, larger occipital* and *lower, smaller supraclavicular triangles.*

Occipital triangle. Boundary. *Anteriorly* it is bounded by the posterior border of the sternocleidomastoid; *posteriorly* by the anterior border of the trapezius, *inferiorly*, it is bounded by the inferior belly of the omohyoid and *superiorly* by the meeting of the anterior and the posterior borders. Its *floor* is formed by the splenius capitis, levator scapulae, scalenus medius and the scalenus posterior from above downwards. Its *roof* is formed by the skin, superficial, and the investing layer of the deep fascia and by the platysma (in the lower part only).

Contents. Dr. K

(i) Accessory nerve.
(ii) Cutaneous branches from the cervical plexus.
  (a) Lesser occipital.
  (b) Transverse cutaneous (anterior cutaneous).
  (c) Supraclavicular nerves.
(iii) Communicating branches from the cervical plexus—
  (a) Branches from C. 3 and 4 to join the accessory nerve.
(iv) Upper part of the brachial plexus.
(v) Supraclavicular branches from the brachial plexus—
  (a) Suprascapular nerve.
  (b) Nerve to the subclavius.
  (c) Long thoracic nerve (nerve to the serratus anterior)
  (d) Nerves to rhomboids.
(vi) External jugular vein and transverse cervical vein.
(vii) Deep cervical lymph glands.

Disposition of the structures. *Accessory nerve.* It pierces through the posterior border of the sternocleidomastoid at its junction of the upper one-third and lower two-thirds and then crosses this triangle obliquely lying in front of the levator scapulae and finally disappears under cover of the lower part of the anterior border of the trapezius. The nerve occupies its position in between the roof (investing layer of deep cervical fascia) and the floor (prevertebral layer of the deep cervical fascia).

Lesser occipital nerve. It arises from the C. 2 and emerges from the upper part of the posterior border of the sternocleidomastoid muscle and hooking around the accessory nerve it ascends upwards to the scalp along the posterior border of the same muscle.

Great auricular nerve. It arises from C. 2 and 3 and emerges in the posterior triangle from behind the posterior border of the sternocleidomastoid below the accessory nerve and soon pierces the deep fascia and runs upwards and forwards obliquely across the superficial surface of the sternocleidomastoid in company with the external jugular vein to the lower part of the lobule of the external ear.

Transverse cutaneous nerve. It arises from C. 2 and 3 and lies below the great auricular nerve and runs forwards transversely across the superficial surface of the sternocleidomastoid muscle.

Supraclavicular nerve. It arises by a common trunk from C. 3 and 4 and lies below the transverse cutaneous nerve and descends vertically downwards through the posterior triangle and divides into three branches lateral, medial and intermediate.

Branches from the 3 and 4. They descend vertically downwards below the accessory nerve and in parallel with it and disappear under cover of the anterior border of the trapezius muscle.

Upper part of the brachial plexus. The roots of the brachial plexus of nerves lie under cover of the scalenus anterior muscle while its trunks appear in the interval between the scalenus anterior and the scalenus medius.

Suprascapular nerve. It arises from the upper border of the upper trunk of the brachial plexus and runs laterally deep to the omohyoid and trapezius.

Nerve to subclavius. It arises from the lower border or from the anterior part of the upper trunk and descending vertically downwards in front of the other trunks of the brachial plexus it disappears under the clavicle to enter into the subclavius muscle.

Long thoracic nerve (nerve to serratus anterior). It arises by three roots from the fifth, sixth and the seventh cervical nerves respectively and the upper two roots pierce the scalenus medius and unite together either within the substance of the muscle or on its lateral surface and then the united trunk descends behind the brachial plexus.

Nerve to rhomboids. It arises from C. 5 and pierces through the scalenus medius muscle and soon disappears under cover of the levator scapulae in company with the deep branch of the transverse cervical artery.

External jugular vein. It passes through the roof of the triangle vertically downwards and backwards and disappears in the lower part of the triangle by piercing through the deep fascia.

Deep cervical Lymph nodes. They lie in chains along the posterior border of the sternocleidomastoid muscle. Some of them are also found along the accessory nerve.

Supraclavicular triangle. It is the lower sub-division of the posterior triangle and intervenes between the inferior belly of the omohyoid and the clavicle.

Boundary. *Superiorly* it is bounded by the inferior belly of the omohyoid, inferiorly by the middle-third of the clavicle and *anteriorly* its *base* is formed by the lower part of the posterior border of the sternocleidomastoid. Its *floor* is formed by the first rib, first digitation of the serratus anterior and by the insertion of the scalenus medius. Its *roof* is formed by the skin, superficial and the deep fasciae and by the platysma.

Contents.

(*i*) Third part of the subclavian artery
(*ii*) Transverse cervical vessels
(*iii*) Suprascapular vessels
(*iv*) Terminal part of the external jugular vein
(*v*) Subclavian vein.
(*vi*) Supraclavicular nerves.
(*vii*) Upper part of the brachial plexus of nerves

Disposition of the structures. *Third part of the subclavian artery.* It arches downwards and laterally from under cover the lateral margin of the scalenus anterior immediately above the clavicle and then passes on to the upper surface of the first rib and finally passes downwards and laterally behind the clavicle to enter into the axilla.

Transverse cervical vessels. The transverse cervical artery and the vein run transversely across the front of the scalenus anterior muscle above the clavicle.

Suprascapular vessels They lie below the transverse cervical vessels and run transversely across the posterior aspect of the clavicle.

Terminal part of external jugular vein. It enters this triangle vertically from above and after piercing the deep cervical fascia it ends into the subclavian vein

Subclavian vein It crosses in front of the lower part of the scalenus anterior muscle and lies behind the clavicle.

Supraclavicular nerves. The three branches of the supraclavicular nerves, lateral, medial and intermediate, lie on the roof of this triangle and cross it vertically to pass over the clavicle.

Upper part of brachial plexus. The brachial plexus of nerves lies partly behind and partly above the third part of the subclavian artery and the nerve roots lie between the scalenus anterior and medius.

Anterior triangle. Boundary. *Anteriorly* it is bounded by the middle line of the neck and *posteriorly* by the anterior border of the sternocleidomastoid. The base is formed by the *base* of the mandible and by a line extending from the angle of the mandible to the mastoid process of the temporal bone. The *apex* is formed by the manubrium sterni where the anterior and the posterior borders meet together.

Subdivisions. Superiorly, the two bellies of the digastric muscle, and inferiorly, the superior belly of the omohyoid muscle, cross the floor of the anterior triangle and subdivide it into smaller triangles enumerated as below:

(1) The triangular area lying above the two bellies of the digastric muscle is known as the *digastric or sub-maxillary triangle.*
(2) The triangular area in between the sternocleidomastoid (sternomastoid) and the superior belly of the omohyoid and the posterior belly of the digastric forms the *carotid triangle.*
(3) The triangular area enclosed by the superior belly of the omohyoid, sternocleidomastoid and the middle line of the neck forms the *muscular triangle.*
(4) The portion lying in between the two anterior bellies of the digastric muscles is known as the *sub-mental triangle.*

Carotid triangle. Boundary. *Above* and *in front* it is bounded by the posterior belly of the digastric. *Below* and *in front* it is bounded by the superior belly of the omohyoid. *Posteriorly* it is bounded by the anterior border of the sternocleidomastoid. The *floor* is formed by the thyrohyoid, hyoglossus and the inferior and the middle constrictor muscles of the pharynx and the *roof* is formed by the skin, superficial fascia, platysma and the deep fascia.

Contents. *Carotid sheath* containing the common carotid artery, internal jugular vein and the vagus nerve, forms the main content. The common carotid artery lies medial to the internal jugular

three molar teeth and from the anterior part of the pterygo-mandibular ligament. The fibres of the buccinator muscle converge towards the angle of the mouth and arrange themselves into upper, middle and lower sets of fibres. The central or middle set of fibres intersect each other at the angle of the mouth and the lower fibres pass to the upper lip to become continuous with the orbicularis oris while the upper fibres join with the orbicularis oris of the lower lip. The upper set of fibres does not decussate and passes to the upper lip while the lower set passes to the lower lip.

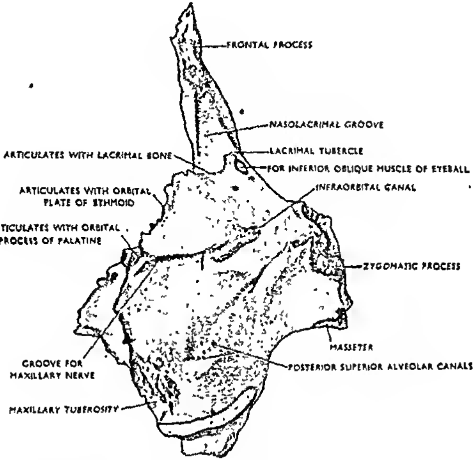


Fig. 488. The right maxilla showing muscular attachments and features. Seen from behind

Nerve supply. It is supplied by the lower buccal branches of the facial nerve.

Action. It is a blowing muscle and compresses the air while blowing. By its action it presses on the food that accumulates between the teeth and the gums and the inner surface of the cheek and thus helps in mastication. It also helps in sucking.

(*c*) The Muscles of the Nose
- Compressor naris.
- Dilator naris.
- Procerus.
- Depressor septi.

Compressor naris. It takes its origin from the anterior surface of the maxilla above and lateral to the incisive fossa, and its fibres run upwards and medially and spread into a thin aponeurosis which passes over the bridge of the nose to become continuous with the fellow of its opposite side and with the aponeurosis of the procerus.

Nerve supply. It is supplied by upper buccal branch of facial nerve.

Action. It compresses the anterior nasal aperture.

Dilator naris. It arises from the margin of the nasal notch of the maxilla and is inserted into the ala nasi.

Nerve supply. It is supplied by upper buccal branch of facial nerve.

Action. It dilates the anterior nasal aperture.

Procerus. It has no bony origin. It arises from the fascia covering the lateral cartilage of the nose and the adjoining part of the nasal bone and is inserted in the skin over the lower part of the forehead opposite the region of the glabella and is continuous with the frontal belly of occipitofrontalis.

Nerve supply. It is supplied by the upper buccal branch of facial nerve.

Action. It draws down the scalp opposite the median plane in the region of the lower part of the forehead and produces wrinkling of the skin in this region.

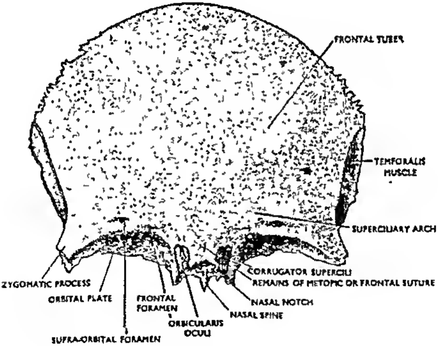


Fig. 489. The frontal bone with attachments. Seen from the front.

Depressor septi. It arises from the incisive fossa on the anterior surface of the maxilla and is inserted into the lower part of the nasal septum which is mobile.

Nerve supply. It is supplied by the upper buccal branch of facial nerve.

Action. It acts in association with the dilator naris and widens the anterior nasal aperture

(*d*) Muscles of the Eye Lid

Orbiculari oculi.
Levator palpebrae superioris.
Corrugator supercilli.

Orbicularis oculi. It is a broad, flat, elliptical muscle which surrounds the orbital opening and spreads on to the eye lid, forehead, cheek and to the temporal region. It consists of three parts namely, orbital, palpebral and lacrimal.

The *Orbital part* of the orbicularis oculi takes origin from the nasal part of the frontal bone, from the lateral surface of the frontal process of the maxilla in front of the anterior lacrimal crest, both above and below the attachment of the medial palpebral ligament, and from the medial palpebral ligament. The upper fibres from above the attachment of the medial palpebral ligament arch round the upper eye lid to the lateral side and then without any interruption, the fibres turn down medially to return round the lower eye lid to the frontal process of the maxilla and gains attachment to it below the medial palpebral ligament. Superiorly some of its upper fibres blend with the frontal belly of occipito-frontalis and the corrugator while some others are inserted in the skin and subcutaneous tissues of the eye brow constituting the *depressor supercilii* muscle.

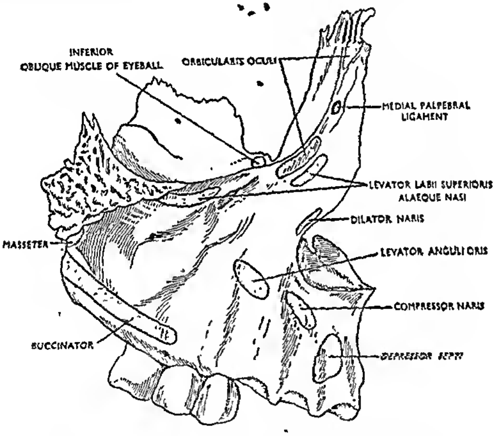


Fig. 490. The right maxilla. Anterior surface. Showing attachments.

The *Palpebral part* of the orbicularis oculi forms thin bundles of muscle fibres in the eye lids which are loosely held together by the subcutaneous connective tissue. The expansions from the levator palpebrae run between these bundles to gain insertion into the skin of the upper lid. It arises mainly from the medial palpebral ligament and partly from the adjoining portions of the bone both above and below the attachment of the medial palpebral ligament. It is inserted into the *lateral palpebral raphe* (not lateral palpebral ligament) which is formed by the interlacement of fibres of the palpebral part of the orbicularis oculi at the lateral commissure of the eye. A thin bundle of fibres of the palpebral part lies along the free margin of the eyelid behind the eyelashes and is called the *ciliary bundle* or *muscle* (of Riolan).

The *lacrimal part* of the orbicularis oculi encloses the lacrimal canaliculi and lies behind the lacrimal sac from which it is separated by the lacrimal fascia. It arises from the fascia covering the lacrimal sac, from the upper part of the crest of the lacrimal bone and from the adjoining portion of the lateral surface of the lacrimal bone behind its crest. Its fibres are divisible into upper and lower slips which pass to the corresponding eyelid. Some of these fibres surround the lacrimal canaliculi and are attached to the tarsal plate while most others pass laterally in the corresponding lid to terminate into the lateral palpebral raphe.

Nerve supply. It is supplied by the temporal and zygomatic branches of the facial nerve.

Action. The orbital part is concerned in tight closure of the eye lids and is a true voluntary muscle. Contraction of the palpebral part closes the eyelids lightly and it is involuntary in action. Contraction of the lacrimal part stretches the lacrimal sac. When the whole muscle contracts it tightly closes the eyelids and draws the skin of the temple, forehead and cheek towards the medial angle of the eye producing wrinklings particularly opposite the lateral angle of the eye where the wrinklings are seen to spread radially from the lateral angle of the eye.

Levator palpebrae superioris. It is a thin small muscle with a much expanded tendon of insertion and is mainly concerned in elevating the upper eyelid and thus it acts as a true antagonist to orbicularis oculi.

Origin. It arises by tendinous fibres from the inferior surface of the lesser wing of the sphenoid just above and in front of the optic canal. At its origin it is not directly connected with the annulus tendinous communis but its tendon of origin remains blended with the tendon of origin of the superior rectus.

Insertion. From its origin it runs forward above the superior rectus muscle and crossing the equator of the eyeball it expands, mostly laterally, to form a broad aponeurosis which splits into *superficial* and *deep lamellae.* The fibres of the superficial lamella can be divisible into strong, prominent, lateral, and indefinite, medial horns or cornua and an intermediate main portion. The fibres of the intermediate main portion end by being attached to the orbital *septum, the superficial aspect* of the superior tarsal plate, to the connective tissue of the eyelid and to the skin; the fibres reaching the skin pass through the fibres of the overlying orbicularis oculi. The *lateral horn* is attached to the front of the lateral palpebral ligament and to the tubercle of Whitnall of the zygomatic bone while the *medial horn* is attached to the posterior part of the medial palpebral ligament.

The *deep lamella* consists of non-striated involuntary fibres (superior tarsal muscle of Müller) and it ends by being attached to the upper border of the superior tarsal plate.

Nerve supply. The striated or voluntary part of the levator palpebrae superioris is supplied by the superior division of the oculomotor nerve. Its involuntary or non-striated part is supplied by branches from the carotid plexus of sympathetics.

Action. The voluntary part raises the upper eyelid as in opening the eye and is a true antagonist to the orbicularis oculi and is responsible for producing the superior palpebral fold. The involuntary part also helps in raising the upper eyelid.

Paralysis of the voluntary part of the muscle causes ptosis and obliteration of the superior palpebral fold. Paralysis of the involuntary part also produces ptosis but it does not affect the superior palpebral fold.

Relations of the levator palpebrae superioris. In the greater part of its course the deep surface of the levator palpebrae superioris lies in direct contact with the superior rectus muscle of the eyeball. At its origin the trochlear nerve crosses it to gain the superior oblique muscle which lies on its medial side. The frontal nerve lies on its

superficial aspect in its course to the supraorbital margin where it divides into supraorbital and supratrochlear nerves. The supraorbital artery appears on its medial margin a little in front of its origin and then runs forward on its superficial aspect. The lateral horn of the levator palpebrae superioris intervenes between the palpebral and orbital portions of the lacrimal gland, the orbital portion lies above it while the palpebral portion lies deep to it and the two parts of the gland are continuous with each other around the free posterior border of the horn.

Corrugator supercilli. It is a small muscle which lies at the medial end of the eyebrow under cover of the orbicularis oculi and the frontal belly of occipitofrontalis. It arises from the medial end of the superciliary arch and arching laterally and upwards it is inserted in the skin opposite middle of the supraorbital margin.

Nerve supply. It is supplied by the temporal branches of the facial nerve.

Action. It draws the eyebrows medially and downwards as in "frowning".

(*e*) Muscles of the Scalp
Occipito-frontalis.
Temporoparietalis. A variable muscle in the temporal region.

The two muscles of the scalp form together the epicranius which lies just subjacent to the *superficial fascia of the scalp.* The superficial fascia of the scalp is dense everywhere except in the temporal regions where it is comparatively looser. It binds the skin and the epicranius together and thus the skin with the epicranius moves as a single unit over the underlying loose cellular layer. Posteriorly the superficial fascia is continuous with the superficial fascia on the back of the neck.

Occipito-frontalis. It is a broad musculo-aponeurotic structure which extends between the eyebrows in front, and, nuchal lines behind and covers the vault of the cranium. It is muscular both in front and behind but aponeurotic in the intervening area known as the *galea aponeurotica* which forms the link between the opposite muscular bellies. It consists of two frontal and two occipital bellies and the galea aponeurotica.

Frontal bellies. The frontal bellies *have no bony attachment.* Each of the frontal bellies arises from the condensed superficial fascia opposite the region of the glabella and the supraorbital margin, and ascends upwards and backwards to terminate into the galea aponeurotica in front of the coronal sature. At its origin, its medial fibres are continuous with the fibres of the procerus, intermediate fibres, with the corrugator supercilli and orbicularis oculi, and the lateral fibres, with the fibres of the lateral part of the latter muscle.

Occipital bellies. Each occipital belly arises from the lateral two-thirds of the superior nuchal line of the occipital bone and from the adjoining part of the mastoid part of the temporal bone. It runs upwards and forwards to become continuous with the galea aponeurotica.

Galea aponeurotica. It is an aponeurotic membrane that covers the vault of the cranium and connects the frontal and occipital bellies together. Posteriorly it extends between the medial margins of the two occipital bellies and is attached to the external occipital protuberance and to the medial portions of the superior nuchal lines. Anteriorly, there being no gap between the medial margins of the frontal bellies, it extends from the anterior margins of the two frontal bellies. Laterally it becomes thinned out and extends over the temporal fascia to the zygomatic arch to which it is attached; the auricularis anterior and superior arise from the galea aponeurotica from each side.

Nerve supply. The occipito-frontalis muscle is supplied by the facial nerve, the frontal bellies by the temporal branches and the occipital bellies by the posterior auricular branches.

Action. By acting alternately the frontal and the occipital bellies of the

occipitofrontalis move the scalp forwards and backwards respectively producing transverse wrinkles over the forehead.

THE MUSCLES AND FASCIA IN THE REGION OF THE NECK

Superficial fascia of the neck. The superficial fascia of the neck is exceedingly thin and is blended with the fibres of the platysma muscle. It cannot be separated from the muscle, which, together with the thin layer of the fascia acts as the superficial fascia.

Platysma.

Platysma. It is a thin sheet of muscle which covers the side of the neck superficial to the deep fascia. It is thin posteriorly but is thicker in front where the muscular fibres are abundantly present. It arises from the deep fascia covering the upper part of the pectoralis major and the anterior part of the deltoid, and then arches over the clavicle and ascends upwards in the neck to reach the base of the mandible. Opposite symphysis menti, its median fibres end by interlacing with each other; succeeding fibres ascend over the mandible and form the risorius muscle of the face and is attached to the skin and subcutaneous tissue of the lower part of the face and to the orbicularis oris opposite the angle of the mouth; its remaining fibres are attached to the base of the mandible below the oblique line.

Action. It causes wrinkles on the side of the neck. It diminishes the gap between the jaw and the neck. Its anterior fibres may help in depressing the mandible.

Nerve supply. It is supplied by the cervical branch of the facial nerve.

Structures found between the platysma and the deep fascia:

(1) External junglar vein.

(2) Cutaneous nerves of the neck, namely, anterior cutaneous, great auricular, supraclavicular nerves and the lesser occipital from the cervical plexus, and the cervical branch of the facial nerve.

Surgical Importance. The superficial wound of the neck severing only the platysma bleeds profusely because the cut edge of the platysma retracts but the bleeding vessels remain open because they cannot retract owing to their wall being fixed with the deep fascia; to stop the bleeding the deep fascia may be required to be cut, so that, the vessels will retract and the haemorrhage will be stopped.

Deep cervical fascia. The deep cervical fascia (fascia colli) forms a general investment for the structures in the region of the neck and is remarkable for the frequency with which it splits and encloses structures. It consists of three distinct layers—(*a*) the general investing layer, (*b*) the pretracheal layer and (*c*) the prevertebral layer.

THE GENERAL INVESTING LAYER. This is the superficial-most layer of the deep cervical fascia and is covered superficially by a thin sheet of muscle known as the platysma; between the platysma and the general investing layer there lie the superficial veins and the cutaneous nerves of the neck. Its attachments are as follows:

Upper attachments

(1) External occipital protuberance.
(2) Superior nuchal line.
(3) Mastoid process.
(4) Zygomatic arch.
(5) Body of the mandible.

Lower attachments

(1) Spine of the scapula and its acromion process.
(2) Clavicle.
(3) Manubrium sterni.

Posterior attachments. Posteriorly it is attached to the ligamentum nuchae throughout its whole length.

DISTRIBUTION. *Transverse disposition.* Transversely, the investing layer, when traced forwards from its posterior attachment, is found to split into two layers at the posterior border of the trapezius muscle, they enclose the muscle, and reaching its anterior border they again reunite to form a single layer which bridges across the intermuscular gap between this muscle and the sternomastoid and thus forms the roof of the posterior triangle. At the posterior border of the sternomastoid it again splits into two layers which enclose the muscle and reaching its anterior border again reunite to form a single layer which roofs in the anterior triangle and reaching the middle line becomes continuous with the fellow of its opposite side. The layer of investing fascia that passes deep to the sternomastoid gives out fibrous processes which enclose the infrahyoid strap muscles. The fascial investments for the strap muscles reunite to form a single layer medially beyond the said muscles and then passes to the median plane in front of the thyroid gland and the trachea to form the *pretracheal layer* and finally becomes continuous with the fellow of the opposite side at the median plane. The pretracheal fascia also passes in front of the carotid system (common carotid artery, internal jugular vein and the vagus nerve) to form the anterior layer of the carotid sheath. From the deep surface of the sternomastoid the investing layer of the deep fascia also gives out a fibrous process which passes deep to the carotid system to form the deep or posterior layer of the carotid sheath.

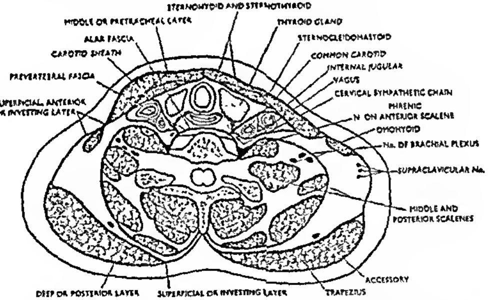


Fig. 491. Chief layers of the deep fascia of the neck below the hyoid bone. Note the relations of the various nerves. The fasciae and fascial spaces shown in this figure are both schematically shown and exaggerated. With kind permission : From W.-H. Hollinshead Ph.D. : Anatomy for Surgeons, Vol. 1 : Paul B. Hoeber; I.N.C., New York.

Vertical disposition. When traced downwards its lower bony attachment is verified; opposite the posterior triangle where it forms the lower part of the roof of the posterior triangle it is found to split into two layers to enclose a space and both these layers afterwards are attached to the clavicle; the structures found between these two layers are the following:

(1) The supraclavicular nerves.
(2) The distal portion of the external jugular vein.
(3) Some lymphatics and cutaneous vessels.

Opposite the lower part of the anterior triangle it also splits into two layers which are attached to the two borders of the suprasternal notch of the manubrium

sterni and enclose a space—the *suprasternal space* (*space of Burns*) which contains the following structures:

(1) Sternal head of the sternomastoid muscle.
(2) Venous arch formed by the terminal portions of the two anterior jugular veins.
(3) Sternal lymph gland.
(4) The interclavicular ligament.

Traced upwards opposite the sub-mandibular region it splits into two lamellae which enclose the submandibular gland; the superficial of these two layers is attached to the base of the mandible while the deep layer is attached to the mylohyoid line of the mandible; in between these two layers, in addition to the submandibular salivary gland, it contains the submandibular lymph gland.

Opposite the interval between the angle of the mandible and the mastoid process it also splits into two layers which enclose the parotid gland; the superficial of the two layers is attached above to the zygomatic arch, the deep one being attached to the base of the skull.

The superficial layer after covering the superficial surface of the parotid gland as it goes up to be attached to the zygomatic arch covers the masseter muscle and this portion of the fasica which is very thick and tense is known as the *parotido-masseteric fascia*.

The portion that extends backwards from the angle of the mandible to the mastoid process is also attached to the lateral aspect of the styloid process of the temporal bone and this portion of the fascia which extends from the angle of the mandible to the styloid process is specially thickened to form the *stylomandibular ligament* which intervenes between the parotid gland above and the submandibular gland below.

To sum up, the investing layer comes into the formation of the following things:

(1) It encloses two muscles—the trapezius and the sternomastoid.
(2) It encloses two spaces—the suprasternal space and the supraclavicular space.
(3) It roofs in the two triangles of the neck—the posterior and the anterior triangles.
(4) It ensheathes two glands—the submandibular and the parotid glands.
(5) It forms the parotido-masseteric fascia and the stylo-mandibular ligament.

Pretracheal fascia.

Horizontal extent. On the deep surface of the sternomastoid muscle the investing layer gives out processes which enclose the strap muscles and then pass across the front of the carotid system, thyroid gland and the trachea, known as the *pretracheal fascia;* it sends out another process which passes behind the carotid system and in front of the prevertebral muscles and the prevertebral fascia to form the posterior layer of the carotid sheath. The pretracheal fascia in its course towards the median plane encloses the thyroid gland.

Vertical extent. Above, it is attached to the hyoid bone and opposite the middle line to the thyroid and the cricoid cartilages. It descends downwards in front of the trachea up to the superior mediastinum where it ends by blending with the fibrous pericardium over the great vessels.

The prevertebral fascia.

Vertical extent. Above, it is attached to the base of the skull, and below, it descends downwards to the superior mediastinum in front of the longus cervicis muscle where it ends on its posterior wall.

Horizontal extent. Like the investing layer of the deep fascia the prevertebral fascia is attached posteriorly to the spines of the cervical vertebrae and to the ligamentum nuchae. Traced forwards it passes deep to the trapezius muscle and reaching its anterior border it covers the floor of the posterior tri- and sends out septa to enclose the muscles in the floor. Opposite the pos-

terior triangle it comes into contact with the investing layer of the deep fascia (together form the fascial carpet of posterior triangle) which forms the roof of the posterior triangle. Lying in between the roof (investing fascia) and the floor (prevertebral fascia) in this situation is the accessory nerve. Lower down in the region above and behind the clavicle the prevertebral and the investing layers of the deep cervical fascia are separated from each other by some space and lying between them are the lower end of the external jugular vein, transverse cervical and suprascapular arteries, the supraclavicular nerves and the posterior belly of omohyoid muscle. From the posterior triangle the fascia descends along the brachial plexus of nerves and the axillary vessels to form the *axillary sheath*. Anteriorly it passes deep to the sternomastoid muscle to reach the lateral aspect of the internal jugular vein and then passes medially deep to the internal jugular vein, the common carotid artery and the vagus nerve (lying deep to the posterior layer of the carotid sheath and scalene fascia) to the transverse processes of the cervical vertebrae to which it is attached. Then it crosses the middle line to become continuous with the fellow of its opposite side.

Surgical Importance. The investment of the pretracheal fascia on the posterior aspect of the thyroid gland is very thin and delicate. Hence, this part of the gland forms its weak spot and any growth of the gland tends to enlarge through this surface which forms the line of least resistance.

The prevertebral layer on the back of the pharynx is adherent to the bucco-pharyngeal fascia opposite the middle line. Thus any collection of pus behind the prevertebral fascia in the neck will push the whole posterior wall of the pharynx forwards (cold abscess). The retro-pharyngeal lymph glands that lie in between the bucco-pharyngeal and prevertebral fasciae, on each side of the median plane, may be the frequent seat of acute inflammation and any collection of pus in this situation will push the wall of the pharynx forwards on one side of the median plane because the two fasciae are adherent opposite the median plane (acute inflammation); due to the extension of the prevertebral and pretracheal fasciae into the mediastinum, inflammatory processes starting in the neck beneath these fasciae may extend into the mediastinum.

Carotid sheath. It is a condensed mass of fibro-areolar tissue which surrounds and embeds the carotid arteries, the internal jugular vein and the vagus nerve and occupies the interval between the transverse processes of the cervical vertebrae behind, the trachea, larynx, pharynx, oesophagus and the lateral lobe of the thyroid gland medially and the sternomastoid muscle laterally.

Constitution of the sheath. The investing layer of the deep cervical fascia reaching the deep surface of the sternomastoid muscle sends out two sheets of fascia—one layer passing in front of the carotid system (common carotid artery, internal jugular vein and the vagus nerve) and the treachea forming the pretracheal layer and the other passes behind the carotid system and in front of the prevertebral fascia to form the posterior layer of the carotid sheath. In the middle line the pretracheal layer after enclosing the thyroid gland is continuous with the fellow of its opposite side. It is now evident that the anterior wall of the sheath is formed by the pretracheal layer and the posterior wall by another deep process that comes from the investing fascia, laterally by the investing fascia between its fascial processes and medially by a condensed mass of fibro-areolar tissue which connects the two layers of the fascia that enclose the carotid system.

Contents of the sheath. It contains the common and the beginning of the external and internal carotid arteries, the internal jugular vein and the vagus nerve. The common carotid artery lies medially, the internal jugular vein laterally and the vagus nerve lies in between and behind them. The constituents of the ansa hypoglossi are in close contact with its anterior wall while the sympathetic trunk lies against its posterior wall.

Sternocleidomastoid (*Sternomastoid.*) This is a long, thick muscle which crosses diagonally each side of the neck from the front of its root to the back of

the head. It is thick and rounded in its centre and is broad and expanded at its ends.

Origin. It consists of two heads of origin, sternal or medial head and clavicular or lateral head. The *sternal head forms* a rounded tendon which arises from the front of the upper part of the manubrium sterni and ascends upwards and laterally. The *clavicular head forms* a flattened band consisting of muscular and aponeurotic fibres and arises from the medial one-third of the superior surface of the medial two-thirds of the clavicle. It ascends vertically upwards under cover of the sternal head and immediately below the middle of the neck it joins with the deep surface of the latter to form a thick muscular belly. The two heads of origin are separated from each other by a triangular interval, the apex of which is directed upwards.

Insertion. The muscular belly thus formed ascends upwards and backwards and reaching the back of the head it becomes flattened and tendinous. It is inserted, by a strong tendon, into the lateral surface of the mastoid process of the temporal bone throughout its whole length and by thin aponeurotic fibres, to the lateral half of the superior nuchal line of the occipital bone above the splenius capitis.

In its course it subdivides the quadrilateral area on the side of the neck into two triangles, anterior and posterior.

Relations. *Superficially* it is covered by the skin, superficial fascia with platysma and the deep fascia and is crossed by the great auricular nerve, external jugular vein and the transverse cervical nerves (anterior cutaneous nerves) from above downwards. Opposite the angle of the mandible it is overlapped by a portion of the parotid gland. The inferior belly of the omohyoid and the posterior belly of the diagastric cross its *deep surface* from behind forwards at some distance from each other and subdivide its deep surface into three parts. Between the omohyoid and its origin it covers the sternoclavicular articulation, sternohyoid and sternothyroid muscles, anterior jugular vein which intervenes between its deep surface and the sternohyoid and sternothyroid muscles, and the carotid sheath. Between the inferior belly of the omohyoid and the posterior belly of the digastric it covers the carotid sheath containing the common carotid artery, commencement of the external and internal carotid arteries, internal jugular vein, the vagus nerve and the ansa cervicalis (hypoglossi). In addition, its anterior part overlaps the superior thyroid, lingual and facial arteries and the common facial and the lingual veins. Above the posterior belly of the diagastric it covers the external and internal carotid arteries, occipital artery, hypoglossal, vagus and accessory nerves, the parotid gland, the stylohyoid muscle and the internal jugular vein. Its posterior part overlaps the splenius capitis, levator scapulae, scalenus medius and anterior and the inferior belly of the omohyoid muscle. It also overlaps the cervical part of the brachial plexus of nerves. The accessory nerve, transverse cervical and the suprascapular arteries emerge into the posterior triangle from under cover of its posterior part. The deep cervical lymph glands lie along its anterior and posterior borders.

Artery supply. It is supplied by the branches from the superior thyroid and occipital arteries.

Nerve supply. It is supplied by the accessory nerve and by branches from the ventral divisions of the second and third cervical nerves. The accessory nerve is its motor nerve while the branches from the second and the third cervical nerves carry proprioceptive sensations (muscle sense) from it.

Actions. Acting together against gravity as in raising the body from recumbent to sitting posture or against resistance they flex the head and the neck on the trunk. Acting singly each muscle draws the head and the neck towards the same shoulder and also rotates the head towards the opposite side as in turning the face towards the opposite shoulder. When the head is fixed the two sternocleidomastoids act as muscles of inspiration by elevating the thorax.

Trapezius. The trapezius muscle is the most superficial muscle of the neck and back and is roughly triangular in form. Seen together the two muscles,

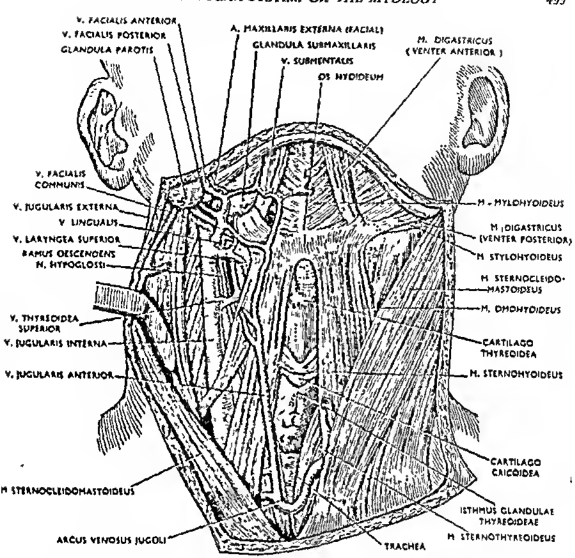


Fig. 492. A dissection of the front of the neck with retraction of sternocleidomastoideus on the right side.
With kind permission : From Callander : Surgical Anatomy, 2nd ed 1939 W B. Saunders Company, Philadelphia and London. Muscles are shown in colours.

one on each side of the median plane on the back, have the semblance of a geometrical trapezium and hence it is named "trapezius".

Origin. It arises by tendinous fibres from the external occipital protuberance, from the medial one-third of the superior nuchal line, from the ligamentum nuchae, from spines of the seventh cervical and all the thoracic vertebrae and from the supraspinous ligaments. From its different origins it forms a flat triangular muscle which may be considered to consist of three portions, *upper, middle* and *lower*.

Insertion. Its *upper fibres* descend downwards and laterally and are inserted into the posterior border of the lateral one-third of the clavicle. The *lower fibres* pass upwards and laterally, form a tendon which glides over the smooth triangular area at the medial end of the spine of the scapula and is inserted into a tubercle on the upper lip of the spine opposite the apex of the smooth triangular area. The *middle fibres* pass transversely and are inserted into the medial margin of the acromion and the upper lip of the spine of the scapula.

Nerve supply. It is supplied by the accessory nerve (motor supply) and by the branches from the ventral divisions of the third and fourth cervical nerves (sensory, proprioceptive).

Actions. The actions of the trapezius are variable subject to whether the muscle works in part or in whole. Its actions also vary depending on whether the scapula is fixed or mobile.

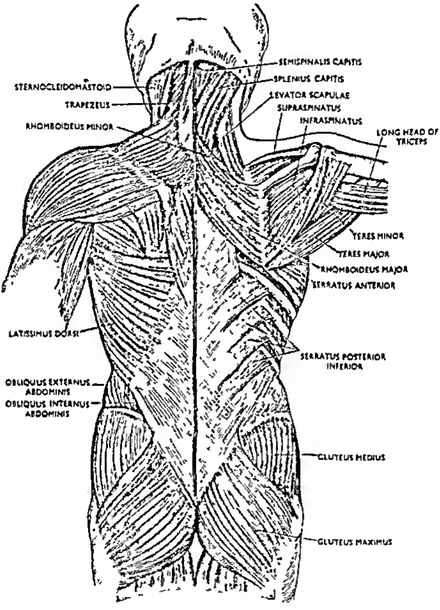
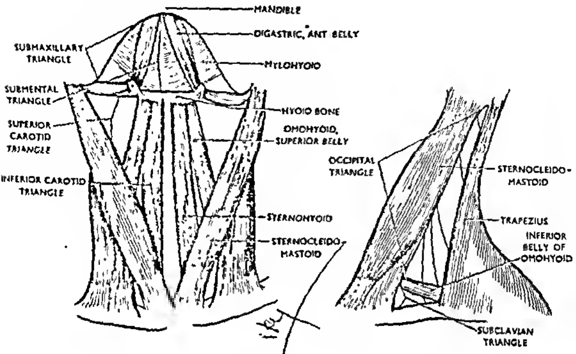


Fig 493 The superficial muscles of the back region. The latissimus dorsi and the trapezius have been removed on the right side.

When the muscle works as a whole, together with the rhomboids it *retracts the scapula* (draws it backwards and medially). Together with the levator scapulae its upper fibres elevate the scapula and the shoulder girdle and thus raise the point of the shoulder. Together with the serratus anterior it rotates the scapula forwards, causes movement of the shoulder girdle and enables the arm to be raised above the head. When the scapula is fixed, acting singly it rotates the head with the atlas at the atlanto-axial joint to the opposite side as in turning the head to the opposite side. With the

vein while the vagus nerve lies in between and behind the artery and the vein. The common carotid artery bifurcates into internal and external carotid arteries opposite the level of the upper border of the thyroid cartilage, the external carotid artery being medial and internal carotid being lateral. Besides the carotid sheath the other structures contained in the carotid triangle are enumerated below together with their dispositions.



A B

Fig. 494. A. Anterior triangle of the neck. B Posterior triangle of the neck.
With kind permission : From W. H. Hollinshead, Ph.D. : Anatomy for Surgeons, Vol. I : Paul B. Hoeber; I.N C., New York.

Disposition of the Structures in the carotid triangle. *Superior thyroid artery.* It arises from the external carotid artery immediately below the greater cornu of the hyoid bone and runs downwards, forwards and medially to disappear under cover of the sternothyroid and sternohyoid muscles.

Superior laryngeal artery. It arises from the medial aspect of superior thyroid artery just before it passes behind the sternohyoid and sternothyroid muscles and then ascends upwards and medially to reach the hyothyroid membrane which it pierces below the internal laryngeal nerve.

Sternomastoid branch of the superior thyroid artery arises from its lateral side and descending downwards and laterally in front of the carotid sheath it enters into the sternocleidomastoid muscle.

Lingual. It arises from the external carotid artery opposite the tip of the greater cornu of the hyoid bone and above the superior thyroid artery and runs upwards, forwards and medially and then descends downwards forming a loop which is crossed by the hypoglossal nerve; it then disappears under cover of the hyoglossus muscle.

Facial artery. It arises from the external carotid artery above the lingual artery and runs upwards, forwards and medially beneath the digastric and stylohyoid to reach the submandibular gland where it is lodged in a groove at its posterior part before entering into the face.

Occipital. It arises from the lateral aspect of the external carotid artery and passes upwards, backwards and laterally superficial to the internal carotid artery and the internal jugular vein. It is crossed by the hypoglossal nerve from behind which hooks round it to pass medially across the internal jugular vein and the external and internal carotid arteries; the point where the hypoglossal nerve hooks under the artery it gives out its descending branch.

Ascending pharyngeal. It arises from the lateral aspect of the external carotid artery immediately above the bifurcation of the common carotid artery and runs upwards in between the external and internal carotid arteries.

Nerves

Hypoglossal. It descends in between the internal carotid artery and the internal jugular vein, and opposite the level of the angle of the mandible it hooks round the occipital artery and turns medially forming an arch with a convexity downwards and crosses both the carotid arteries and the loop of the lingual artery and then disappears by passing between the mylohyoid and the hyoglossus.

The *descending branch* from the hypoglossal nerve descends downwards either in front of the carotid sheath or through the carotid sheath and after giving a branch to the superior belly of the omohyoid joins with the second and the third cervical nerves to form the ansa (hypoglossi) cervicalis.

The *thyrohyoid branch* from the hypoglossal nerve arises from it opposite the posterior border of the hyoglossus muscle. Crossing obliquely over the greater cornu of the hyoid bone it ends in the thyrohyoid muscle.

Vagus nerve. It passes through the carotid sheath lying in between and behind the common carotid artery and the internal jugular vein.

Internal laryngeal nerve. It is a branch of the superior laryngeal nerve (branch of vagus) and pierces the thyrohyoid membrane above the superior laryngeal artery.

External laryngeal nerve. It is a branch of the superior laryngeal nerve which descends downwards and medially and lies postero-medial to the superior thyroid artery. It ends in the cricothyroid muscle

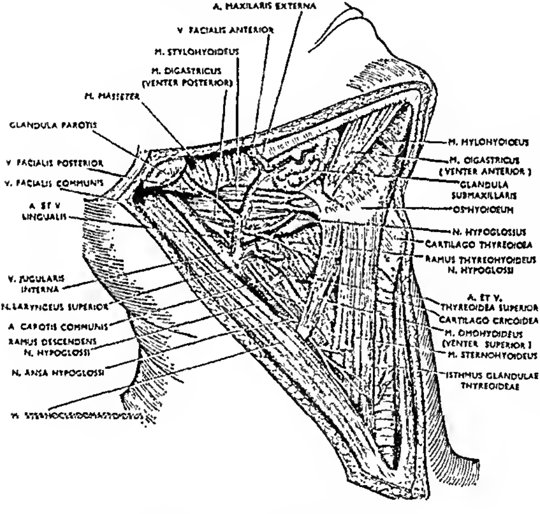


Fig. 495. The dissection of the anterior triangle of the neck. Right side.
With kind permission : From Callander : Surgical Anatomy, 2nd ed., 1939. : W. B. Saunders Company, Philadelphia and London.

Accessory nerve. It lies in the superior angle of the carotid triangle and descending in front of the internal jugular vein it crosses to its lateral side and then enters into sternocleidomastoid by passing beneath the posterior belly of the digastric and the stylohyoid muscles. It soon disappears by passing into the substance of the sternocleidomastoid muscle.

Sympathetic nerve trunk. It lies behind the carotid sheath and in front of the transverse processes of the cervical vertebrae.

ANSA CERVICALIS (HYPOGLOSSI). It is formed by the union of the descendens hypoglossi and the branches of the second and the third cervical nerves and lies *either in front of or behind the carotid* sheath. From the ansa three branches arise which supply the sternohyoid, sternothyroid and the inferior belly of the omohyoid muscle. The descendens hypoglossi at first descends in front of the internal jugular vein and then crosses it to its medial side where it is joined by the descendens cervicalis (C. 2, 3) which crosses the internal jugular vein from above downwards, forwards and medially.

OTHER STRUCTURES. *Carotid body.* It is a small reddish body resembling a large pin's head and is placed at the bifurcation of the common carotid artery. The following structures are also found in the triangle:

Part of the larynx and trachea.
Greater cornu of the hyoid bone.
Lymph glands and lymph vessels.

Muscular triangle. BOUNDARIES.
Anteriorly. By the middle line of the neck.
Posteriorly and above. By the superior belly of the omohyoid.
Posteriorly and below. By the lower part of the anterior border of the sternocleidomastoid muscle.

CONTENTS. (1) MUSCLES.
(a) *Sternohyoid.* It lies in front of the trachea on each side of the median plane.
(b) *Sternothyroid.* It lies in front of the trachea deep to sternohyoid.
(c) *Cricothyroid.* It extends from the cricoid to the thyroid cartilage under cover of the sternohyoid and sternothyroid.
(d) *Levator glandulæ thyroidi.* It extends from the thyroid isthmus to the hyoid bone on either side of the median plane.

(2) VESSELS. (a) *Superior thyroid.* It passes obliquely behind the sternohyoid and sternothyroid muscles to reach the thyroid gland. Its crico-thyroid branch passes in front of the crico-thyroid membrane and forms an arterial arch by anastomosing with the fellow of its opposite side. Above the isthmus of the thyroid its anastomosing branch forms another arterial arch by joining with the fellow of its opposite side.

(3) NERVES. (a) Nerve to the sternohyoid and sternothyroid from the ansa cervicalis (hypoglossi).
(b) *External laryngeal nerve.* It enters the cricothyroid muscle behind the upper end of the sternohyoid and sternothyroid muscles.
(c) *Recurrent laryngeal nerve.* It lies at first in the groove between the trachea and the oesophagus and then passes deep to the posterior surface of the thyroid gland and finally enters into the larynx by passing below the articulation between the inferior cornu of the thyroid with the cricoid cartilage.

(4) OTHER STRUCTURES.
(a) Larynx and trachea.
(b) Thyroid gland.
(c) Oesophagus.

Digastric triangle or the submandibular triangle. BOUNDARY.
Below and in front. By the anterior belly of the digastric.
Below and behind. By the posterior belly of the digastric and the stylohyoid.
Above. By the base of the mandible and by a line joining the angle of the mandible to the mastoid process of the temporal bone.
Roof. By the skin, superficial fascia, platysma and the deep fascia.
Floor. By the mylohyoid and hyoglossus muscles.

CONTENTS (1) MUSCLES.
(a) *Styloglossus.* It lies on the upper part of the superficial surface of the hyoglossus muscle and is placed on a level higher than the stylopharyngeus.
(b) *Stylopharyngeus.* It lies on the lower part of the hyoglossus muscle and then passes in between the superior and middle constrictor muscles of the pharynx. On its inferior aspect there lies the glossopharyngeal nerve which gives a twig to the muscle.

(2) ARTERIES. (a) *Fascial artery.* It grooves in the posterior part of the submandibular gland and at the lower border of the body of the mandible it gives out its submental branch.
(b) *Mylohyoid branch of the inferior dental artery.* It lies under cover of the body of the mandible in the mylohyoid groove.
(c) *Terminal portion of the external carotid artery.* It ascends upwards to enter into the substance of the parotid gland.
(d) *Internal carotid artery.* It lies postero-lateral to the external carotid artery.

(3) VEINS. (a) *Internal jugular vein.* It lies lateral to both internal and external carotid arteries.
(b) *Facial (Anterior) vein.* It passes superficial to the superficial portion of the submandibular gland and joins with the anterior division of the (*posterior facial vein*) *retromandibular vein* which ends in the internal jugular vein by crossing the carotid sheath.

(4) NERVES. (a) *Mylohyoid branch of the inferior dental nerve.* It lies along with the corresponding artery. It gives out a branch which enters the posterior border of the anterior belly of the digastric muscle and supplies it.

(b) *Glossopharyngeal nerve.* It lies on the inferior aspect of the stylopharyngeus muscle to which it gives branches and along with it passes in between the superior and middle constrictors of the pharynx.
(c) *Vagus.* It lies deep to internal carotid artery and the internal jugular vein.
(d) *Hypoglossal nerve.* It lies in between the mylohyoid and hyoglossus below the submandibular duct.
(e) *Lingual nerve.* It lies in between the mylohyoid and the hyoglossus and above the submandibular duct and more anteriorly it is crossed by the submandibular duct.

(5) OTHER STRUCTURES
(a) *Submandibular gland with its duct.*
(b) *Lower portion of the parotid gland.*
(c) *Submandibular ganglion.* It is small rounded ganglion suspended from the lower border of the lingual nerve by two roots and lies above the deep part of the submandibular gland and provides two short branches to the submandibular gland in the situation.

Submental triangle. BOUNDARY
On either side By the anterior belly of the digastric.
Apex By the union of the two anterior bellies of the digastric
Base By the body of the hyoid bone
Floor By the mylohyoid muscles.

CONTENTS.
(a) *Anterior jugular vein*
(b) *Submental lymph gland.*

INFRAHYOID MUSCLES OF THE DEPRESSOR MUSCLES OF THE HYOID BONE.

Omohyoid. It is a flat ribbon-shaped muscle which traverses through both the triangles (anterior and posterior) of the neck and consists of two fleshy bellies, inferior and superior, and an intermediate tendon.

Origin. The *Inferior belly* arises from the superior border of the scapula close to the suprascapular notch and also from the suprascapular ligament, and by crossing the posterior triangle it ends into the intermediate tendon under cover of the sternocleidomastoid muscle. In its course upwards and forwards through the posterior triangle the inferior belly of omnhyoid subdivides the posterior triangle into occipital and subclavian triangles.

Insertion. The *Superior belly* arises from the intermediate tendon and ascends vertically upwards to gain its insertion to the lower border of the body of the hyoid bone below the mylohyoid and lateral to the sternohyoid muscle.

The intermediate tendon lies under cover of the sternocleidomastoid over the internal jugular vein opposite the level of the cricoid cartilage. The muscle is ensheathed by the deep cervical fascia and a fascial process anchors the intermediate tendon to the clavicle.

Nerve supply. The superior or the anterior belly is supplied by a branch from the descendens hypoglossi and the posterior belly is supplied by a branch from the ansa cervicalis (hypoglossi).

Action. It depresses the larynx and the hyoid bone after their elevation by the suprahyoid muscles.

Sternohyoid. This is a thin, strap-like, bilateral muscle which ascends vertically upwards, one on each side of the median plane, superficial to the thyroid gland, to its insertion in the hyoid bone.

Origin. It arises from the posterior surface of the manubrium sterni, from the capsule of the sternoclavicular joint and from the posterior surface of the clavicle close to its sternal end.

Insertion. It is inserted into the lower border of the body of the hyoid bone below the mylohyoid muscle and medial to the superior belly of the omohyoid.

Nerve supply. It is supplied by a branch from the ansa cervicalis (hypoglossi) (C. 2-3).

Action. Same as omohyoid.

Sternothyroid. *Origin.* It occupies a deeper plane than the sternohyoid

and arises from the back of the manubrium sterni and from the adjacent portion of the first costal cartilage.

Insertion. It is inserted into the oblique line of the thyroid cartilage.

Nerve supply. It is supplied by a branch from the ansa cervicalis (C. 2-3).

Thyrohyoid. It is a small quadrilateral muscle which arises from the oblique line of the lamina of the thyroid cartilage and is inserted into the lower border of the greater cornu of the hyoid bone close to the body.

Nerve supply. It is supplied by first cervical nerve through hypoglossal nerve.

Action. Same as other infrahyoid muscles.

THE SUPRAHYOID MUSCLES OR THE ELEVATOR MUSCLES OF THE HYOID BONE.

(1) Digastric.
(2) Mylohyoid.
(3) Stylohyoid.
(4) Hyoglossus.
(5) Geniohyoid.
(6) Genioglossus.

Digastric. It consists of an anterior and a posterior belly and an intermediate tendon which connects the two bellies together. The posterior belly arises from the digastric notch or fossa behind the mastoid process of the temporal bone and running downwards and forwards it ends into the intermediate tendon.

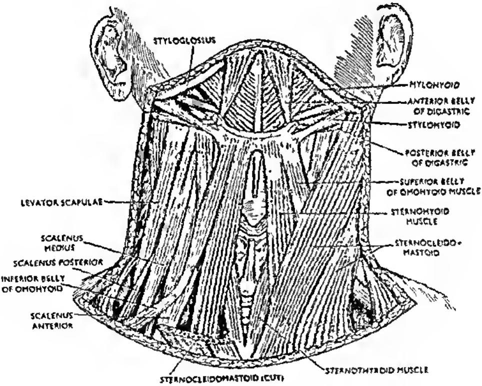


Fig. 496. The muscles on the antero-lateral regions of the neck.

The anterior belly arises from the digastric fossa of the mandible and running downwards and backwards it ends into the intermediate tendon. The intermediate tendon of the digastric muscle pierces through the stylohyoid muscle and sends out an aponeurotic fold which is arranged in the form of a loop and connects it with the body and greater cornu of the hyoid bone. The inner surface of the loop is occasionally lined by synovial membrane.

Nerve supply. The anterior belly is supplied by a branch from the mylohyoid nerve while the posterior belly is supplied by a branch from the facial nerve.

1. *Structures crossing superficial to the posterior belly of the digastric.*
   (i) The anterior division of the posterior facial vein and the anterior facial vein after crossing the posterior belly of the digastric unite together to form the common facial vein.
   (ii) Great auricular nerve from the cervical plexus.
   (iii) Cervical branch of the facial nerve.
2. *Structures crossing deep to the posterior belly of the digastric.*
   (i) Internal jugular vein.
   (ii) Internal carotid artery.
   (iii) External carotid artery with its lingual, facial and occipital branches.
   (iv) Vagus, accessory and the hypoglossal nerves.

Mylohyoid. It is a triangluar muscular sheet which lies deep to the anterior belly of the digastric and together with the fellow of its opposite side it forms the floor of the mouth.

Origin. It arises from the anterior three-fourths of the mylohyoid line on the inner surface of the mandible.

Insertion. Its anterior and middle fibres are inserted into the median raphe whereas its posterior fibres are inserted into the lower part of the body of the hyoid bone below the geniohyoid and above the omohyoid and sternohyoid muscles.

Relation. The *inferior* or *superficial surface* of the mylohyoid is in relation with the skin, superficial fascia, platysma and deep fascia, anterior belly of digastric, superficial part of submandibular gland, mylohyoid vessels and nerve and with the facial and submental vessels. The *superior* or *deep surface* is in relation with the lingual and hypoglossal nerves and the submandibular ganglion, the deep portion of the submandibular gland and its duct, the sublingual gland and a small part of the lingual and sublingual vessels; the hyoglossus, geniohyoid and the styloglossus muscls lie deep to mylohyoid.

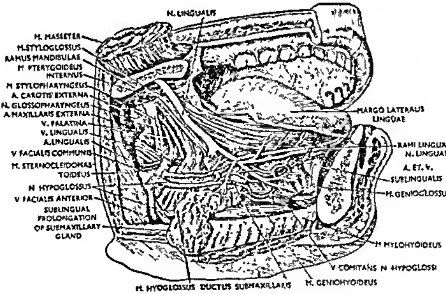


Fig. 497. The submandibular region of the neck. The mandible has been removed. With kind permission : From Callander : Surgical Anatomy, 2nd ed., 1939. : W. B. Saunders Company, Philadelphia and London.

Nerve supply. It is supplied by the mylohyoid branch of the inferior dental nerve.

Stylohyoid. It has been described under the head "Muscles attached to the styloid process".

Hyoglossus. It arises from the whole length of the greater cornu and the lateral part of the front of the body of the hyoid bone.

Its fibres ascend vertically upwards and are inserted into the lateral side of the tongue between the styloglossus and the longitudinalis linguae inferior.

Nerve supply. It is supplied by a branch from the hypoglossal nerve.

Geniohyoid. It arises from the lower genial tubercles on the inner surface of the symphysis menti.

It is inserted into the anterior aspect of the body of the hyoid bone extending both above and below the ridge on the anterior aspect of the body.

Nerve supply. It is supplied by a branch from the hypoglossal nerve.

Genioglossus. It arises from the upper genial tubercles on the inner surface of the symphysis menti of the mandible.

Its fibres spread in a fan-shaped manner and its upper and middle fibres are inserted into the side of the tongue but its lower fibres descend downwards to be inserted into the upper border of the body of the hyoid bone.

Nerve supply. Same as above.

THE MUSCLES OF MASTICATION

The muscles of mastication are the following:

(1) Temporalis.
(2) Masseter.
(3) Pterygoideus lateralis.
(4) Pterygoideus medialis.

– **Temporal fascia.** It is a strong fascia that covers the superficial aspect of the temporalis muscle. Above it is attached to the superior temporal line of the frontal and parietal bones and to the supramastoid crest of the temporal bone. Inferiorly it splits into two layers which are attached to the lateral and medial margins of the upper border of the zygomatic arch and thus encloses a space which contains a small quantity of fat, the zygomatico-temporal branch of maxillary nerve and the zygomatic branch of the superficial temporal artery.

Superficially in the upper part, it is covered by the orbicularis oculi, auricularis anterior and superior and the galea aponeurotica. Posteriorly in front of the external acoustic meatus the superficial temporal vessels and the auriculotemporal nerve cross this fascia superficially from below upwards. The deep surface of the temporal fascia gives origin to some of the fibres of the temporalis muscle.

Temporalis. It is a large fan-shaped muscle which occupies the temporal fossa of the skull and connects the cranium with the mandible.

Origin. It arises from the whole of the temporal fossa formed by the squamous part of the temporal bone, by the greater wing of the sphenoid above the infratemporal crest and by the parietal bone below the inferior temporal line and from the deep surface of the temporal fascia.

Insertion. It forms a thick tendon which passes through the gap medial to the zygomatic arch and is inserted into the medial surface, anterior border and the apex of the coronoid process and to the anterior border of the ramus of the mandible.

Nerve supply. It is supplied by the deep temporal branches of the mandibular nerve (anterior division).

Action. It elevates the mandible as in closing the mouth. It also retracts it after it has been protruded.

Masseter. It is a quadrilateral-shaped, superficial muscle which extends from the zygomatic arch of the cranium to the ramus of the mandible.

Origin. It consists of three sets of fibres, *superficial*, *middle* and *deep*. The *superficial set of fibres* arises by aponeurotic fibres from the anterior two-thirds of the lower border of the zygomatic arch including the zygomatic process of the maxilla; the *middle set* arises from the deep surface of the zygomatic arch and from the posterior-third of its lower border; the *deep set of fibres* takes origin from the deep surface of the zygomatic arch only.

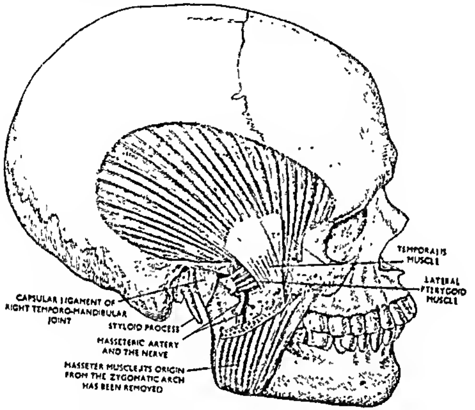


Fig 498. The temporo-mandibular region on the right side. The zygomatic arch and a portion of the masseter muscle have been removed

Insertion. The three sets of fibres blend together anteriorly and descend vertically downwards and backwards to gain insertion into the lateral surface of the ramus and the adjoining portion of the coronoid process of the mandible.

The superficial set of fibres is attached to the lateral surface of the angle and the lower half of the ramus of the mandible; the middle set is attached to the middle of the ramus while the deep set of fibres is attached to the upper part of the ramus and adjoining portion of the coronoid process of the mandible.

Nerve supply. It is supplied by the masseteric branches of the mandibular nerve.

Action. It elevates the mandible from the position of opened-up jaws, brings the mandibular teeth in oclusion with the maxillary teeth, and in continued action, exerts force of compression between them as in clenching the teeth.

Relations. The muscle is covered *superficially* by the skin, platysma, parotid fascia (parotido-masseteric fascia), risorius and the zygomaticus major muscles; it is overlapped from behind by the parotid gland and is crossed transversely by the parotid duct, the zygomatic and the buccal branches of the facial nerve and the transverse facial branch of the superficial temporal artery; the accessory parotid gland lies over it above the parotid duct, and the parotid lymph gland lies between it and the parotid fascia; its antero-inferior part is crossed by the anterior facial vein. Its *deep surface* covers the ramus of the mandible and the insertion of the temporalis muscle; anteriorly its deep surface is ' from the buccinator muscle by the sucktorial pad of fat.

Pterygoideus lateralis. In contrast to the other muscles of mastication which extend vertically, the lateral pterygoid muscle lies essentially in the horizontal plane.

Origin. Its arises by two heads, upper and lower. The *upper head* arises from the infratemporal surface and infratemporal crest of the greater wing of the sphenoid, and the *lower head* arises from the lateral surface of the lateral pterygoid plate.

Insertion. The muscle fibres of each head run backwards and laterally and the two heads blend together at their insertion. The fibres of the upper head are inserted primarily into the anterior portion of the capsule and the articular disc of the temporomandibular joint, and into the upper portion of the neck of the mandible; the fibres of the lower head are inserted below the fibres of the upper head on the front of the neck of the mandible.

N.B.—According to some anatomists (Harpman and Woolward the tendon of lateral pterygoid during embryonic life passes through the temporomandibular joint to the malleus and it is this intra-articular portion of the tendon which later on develops into the intra-articular disc. Thus the insertion of lateral pterygoid into the disc is self explanatory

Nerve supply. It is supplied by a branch from the anterior trunk of the mandibular nerve.

Action. It depresses the mandible, as in opening the mouth, by drawing the condyle and the articular disc forwards; by acting together with the medial pterygoid it moves the mandible from side to side as in chewing; it also protrudes the mandible forwards together with the medial pterygoid.

Relations. The main structures found under cover of *deep surface* of the lateral pterygoid are the mandibular nerve with its branches and the otic ganglion, the branches from the first and second parts of the maxillary artery, the chorda tympani nerve, the sphenomandibular ligament and the medial pterygoid muscle. Its *superficial surface* is related to the ramus of the mandible, the tendon of the temporalis muscle and to a part of the deep surface of the masseter muscle. The lingual nerve and the inferior alveolar nerve and vessels descend downwards and forwards from its lower border. The masseteric nerve and the deep temporal vessels and nerves ascend upwards from its upper margin. The buccinator nerve passes between the two heads of the lateral pterygoid muscle and then passes downwards and forwards to reach the face.

The *inferior dental* nerve arises from the posterior division of the mandibular nerve and descends vertically downwards behind the lingual nerve and accompanying the inferior dental artery enters the mandibular canal through the mandibular foramen.

The auriculotemporal nerve arises by two roots from the posterior division of the mandibular nerve and they embrace the middle meningeal artery before joining to form the nerve trunk.

The *chorda tympani branch* of the facial nerve descends downwards and forwards crossing deep to the roots of the auriculotemporal nerve, middle meningeal artery and the inferior dental vessels and nerves, and joins the posterior border of the lingual nerve behind the lateral pterygoid muscle. It supplies taste fibres to the anterior two-thirds of the tongue and secretomotor fibres to the sublingual and submandibular glands through submandibular ganglion.

Pterygoideus medialis. *Origin.* It arises from the medial surface of the lateral pterygoid plate of the pterygoid process of the sphenoid and also from the grooved surface of the tubercle of the palatine bone.

Insertion. It is inserted by a thick tendon into the medial surface of the angle and the adjoining part of the ramus of the mandible as far as the mandibular foramen.

Nerve supply. It is supplied by a branch from the trunk of the mandibular nerve.

Actions. Its actions are similar to that of the lateral pterygoid muscle.

MUSCLES ATTACHED TO THE STYLOID PROCESS OF THE TEMPORAL BONE

The muscles attached to the styloid process are (1) the Styloglossus, (2) Stylopharyngeus and (3) the Stylohyoid muscle.

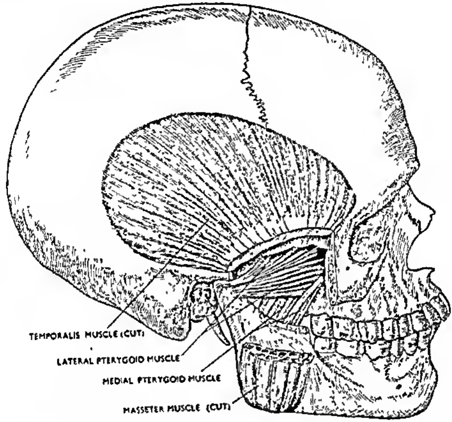


Fig 499. The infratemporal region exposed to show the pterygoid muscles

Styloglossus. It is the shortest of the styloid group of muscles and it arises from the anterior and lateral aspects of the styloid process close to its apex and from the stylomandibular ligament. Its fibres pass downwards and forwards and reaching the side of the tongue they divide into longitudinal and oblique portions. The longitudinal portion ends by blending with the longitudinalis linguae inferior in front of the hyoglossus while the oblique portion overlaps the hyoglossus muscle and ends by decussating with its fibres.

Nerve supply. It is supplied by the hypoglossal nerve.

Actions. It draws the tongue upwards and backwards.

Stylopharyngeus. It arises from the medial side of the styloid process of the temporal bone close to its base. It descends along the side of the pharynx and passes between the superior and middle constrictor muscles of the pharynx along with the glossopharyngeal nerve. Some of its fibres are lost in the pharyngeal wall while majority of the fibres are inserted into the posterior border of the thyroid cartilage along with the palatopharyngeus. The glossopharyngeal nerve winds round its posterior border near its origin to gain its lateral aspect.

Nerve supply. It is supplied by a branch from the glossopharyngeal nerve.

Actions. The stylopharyngeus muscle along with other pharyngeal muscles . the larynx upwards behind the hyoid bone during deglutition.

Stylohyoid muscle. It arises by a small tendon from the posterior and lateral aspects of the styloid process of the temporal bone close to its base and descending

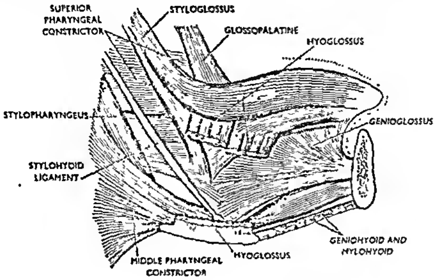


Fig. 500. The musculature of the tongue, with the hyoglossus largely removed.
With kind permission : *From W. H. Hollinshead, Ph D.: Anatomy for Surgeons,* Vol. I. : Paul B. Hoeber; New York.

downwards and forwards, it is inserted into the body of the hyoid bone at its junction with the greater cornu and just above the omohyoid muscle. Near its insertion it is pierced by the tendon of digastric.

Nerve supply. It is supplied by a branch from the facial nerve.

Actions. Along with other suprahyoid muscles it elevates the hyoid bone and the floor of the mouth during deglutition and steadily fixes the hyoid bone so as to allow the middle constrictor muscle of the pharynx to work on the pharynx.

THE FASCIAE AND THE DEEP MUSCLES OF THE BACK

The deep muscles of the back extend from the pelvis to the skull and form the complex intrinsic muscles of the trunk. They are enumerated as below:

- Splenius capitis.
- Splenius cervicis.
- Erector spinae (sacrospinalis).
- Interspinales.
- Transversospinalis.
- Intertransversarii.
- Multifidus.
- Rotatores
- Semispinalis.

Deep fascia. The deep fascia of the neck is the deep cervical fascia and has already been described. The deep fascia of the back is called the thoracolumbar fascia or the lumbo-dorsal fascia or the lumbar fascia.

Thoracolumbar fascia (*Lumbar fascia or Lumbo-dorsal fascia*). It covers the deep muscles of the back and is continuous above with the deep fascia of the neck. In the thoracic region it is less thick and separates the muscles of the back from the muscles of the superior extremity.

In the lumbar region it is thick and membranous and consists of three layers—*anterior*, *middle* and *posterior*. The *anterior layer of the lumbar fascia* is comparatively thin and covers the quadratus lumborum muscle from in front. Medially it is attached to the anterior surface of the transverse processes of the lumbar vertebrae and separates the quadratus lumborum from the psoas major muscle and is continuous with the psoas fascia in this situation. Laterally at the lateral border of the quadratus lumborum it fuses with the middle layer and then is continuous with the transversalis fascia. Superiorly it forms the lateral arcuate ligament and is attached to the lower border of the last rib. Inferiorly it is attached to the iliolumbar ligament and to the adjoining part of the inner lip of the iliac crest. The *middle layer* covers the posterior aspect of the quadratus lumborum and is attached medially to the tips of the transverse processes of the lumbar vertebrae. Laterally at the lateral border of the quadratus lumborum it blends with the anterior layer and at the lateral border of the sacrospinalis it blends with the posterior layer. Superiorly it is attached to the lower border of the last rib and the lumbocostal ligament. Inferiorly it is attached to the inner lip of the iliac crest. The *posterior layer* of the lumbar fascia is the thickest of all and is membranous in character. Medially it is attached to the tips of the spinous processes of the lumbar and sacral vertebrae and to the supraspinous ligaments. Laterally at the lateral border of the sacrospinalis it fuses with the middle layer. It covers the sacrospinalis muscle posteriorly and gains its attachment to the posterior-fourth of the iliac crest lateral to the origin of the sacrospinalis muscle. Superiorly it is fused with the fascia covering the latissimus dorsi.

The posterior and the middle layers fuse together at the lateral border of the sacrospinalis and then the two fused lamellae join with the anterior lamella at the lateral border of the quadratus lumborum to form a common aponeurosis from which the transversus abdominis arises.

Splenius capitis. It arises from the spines of the upper four dorsal vertebrae, from the spine of the seventh cervical vertebra and from the lower-half of the ligamentum nuchae. It passes upwards and laterally and is inserted into the mastoid process of the temporal bone and to the lateral one-third of the superior nuchal line of the occipital bone under cover of the sternomastoid muscle. Its upper part forms a part of the floor of the posterior triangle being placed above the levator scapulae.

Nerve supply. It is supplied by the lateral branches of the posterior primary rami of the fourth and fifth cervical nerves.

Actions. Acting together they draw the head backwards, and acting singly, it causes lateral flexion of the head and also rotates the head slightly medialwards so that the face is drawn to the same side.

Splenius cervicis. *It takes its origin from the spines of the third to the sixth* cervical vertebrae and is inserted into the posterior tubercles of the transverse processes of the first, second or the third cervical vertebrae and lies under cover of the levator scapulae.

Nerve supply. It is supplied by the lateral branches of the posterior primary rami of the lower cervical nerves.

Actions. Same as splenius capitis.

Erector spinae (*Sacrospinalis*). It is a thick muscle that fills up the hollow between the vertebral spines and the angles of the rib. It takes its origin from an aponeurosis which has an U-shaped attachment. Medially its aponeurotic origin is attached to the sacral spines and the spines of the lumbar and the eleventh and the twelfth thoracic vertebrae and laterally to the transverse tubercles of the sacrum, part of the iliac crest and to the sacrotuberous and sacroiliac ligaments. From this aponeurotic origin it ascends upwards and is succeeded by muscular fibres in the lumbar region and forms a thick mass of muscle fibres. It then splits up into three groups of muscular bands, the *spinalis*, the *longissimus* and the *iliocostocervicalis*.

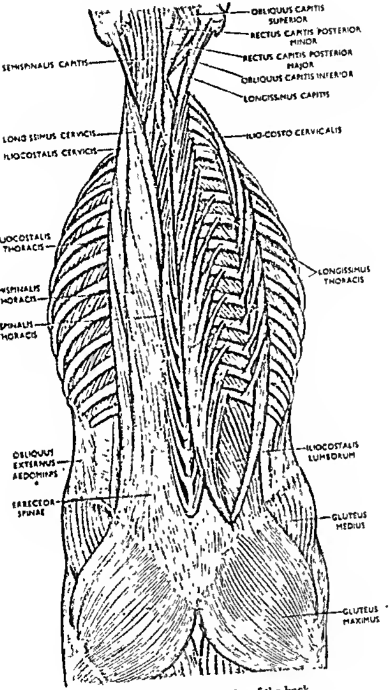


Fig. 501. The deep muscles of the back.

Each of these three muscle groups subdivides into three relays of muscle groups and each relay replacing the other lies on the medial side of the replaced one. The following are the subdivisions of each muscle group.

SPINALIS (Most medial column of muscle)

(a) Spinalis thoracis.
(b) Spinalis cervicis.
(c) Spinalis capitis.

LONGISSIMUS (Intermediate column of muscle)

(a) Longissimus thoracis.

(*b*) Longissimus cervicis.
(*c*) Longissimus capitis.

Iliocosto-cervicalis (Lateral column of muscle)
(*a*) Iliocostalis.
(*b*) Costalis.
(*c*) Costocervicalis.

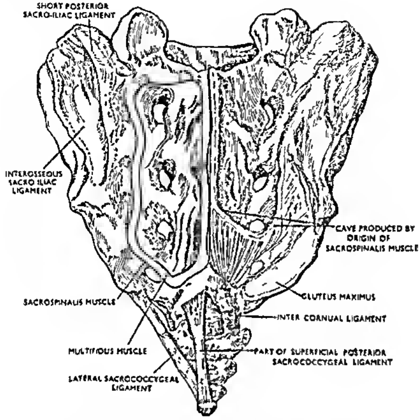


Fig. 502. The dorsal view of the sacrum and coccyx showing muscular and ligamentous attachments.

Spinalis thoracis. It is the most medial prolongation of the erector spinae and lies medial to the longissimus with which it is intimately blended. It arises by three or four small tendons from the spines of the first and second lumbar, and eleventh and twelfth thoracic vertebrae. From different origins it forms a fleshy belly which again splits into tendons which are inserted into the spines of the upper thoracic vertebrae. The deep surface of the muscle is intimately blended with semispinalis thoracis.

Nerve supply. It is supplied by dorsal rami of lower thoracic nerves.

Actions. It is the extensor of the vertebral column.

Spinalis cervicis. It is an inconstant muscle. It may arise from the lower part of the ligamentum nuchae and from the seventh cervical spine and is inserted into the spine of the axis. Both its origin and insertions are variable.

Nerve supply. It is supplied by dorsal rami of the lower cervical nerves.

Actions. Same as above.

Spinalis capitis. It is usually inseparably blended with the semispinalis capitis.

Longissimus thoracis. It is the largest subdivision of the erector spinae and lies between the spinalis group on the medial side and iliocosto-cervicalis on the lateral side. It arises in the lumbar region from the accessory processes and the dorsal aspects of the transverse processes of all the lumbar vertebrae and from the middle layer of the lumbar fascia. It is inserted in the thoracic region by lateral fleshy slips and medial tendinous slips. The lateral fleshy slips are attached to the back of the lower nine or ten ribs between their angles and the tubercles. The medial tendinous slips are attached to the tips of the transverse processes of all the thoracic vertebrae.

Nerve supply. It is supplied by the dorsal rami of the lower thoracic and lumbar nerves.

Actions. It is the extensor and lateral flexor of the vertebral column (Dorsi-lumbar region).

Longissimus cervicis. It relays with longissimus thoracis and commences at the medial aspect of the latter. It arises by small tendons from the transverse processes of the upper four or five thoracic vertebrae and is inserted by tendinous slips into the posterior tubercles of the transverse processes of all the cervical vertebrae except the first and the seventh.

Nerve supply. It is supplied by the dorsal rami of the upper thoracic and cervical nerves.

Actions. It is the extensor and lateral flexor of the cervico-dorsal region of the vertebral column.

Longissimus capitis. It intervenes between the longissimus cervicis and the semispinalis capitis. It arises by tendons from the transverse processes of the upper four or five thoracic vertebrae and from the articular pillars of the lower three or four cervical vertebrae. It is inserted into the lower border of the mastoid process of the temporal bone deep to the *sternocleidomastoid* and the *splenius capitis*.

Nerve supply. It is supplied by the dorsal rami of the lower cervical nerves.

Actions. It extends the head and turns the face to the same side.

Iliocosto-cervicalis. This forms the most lateral group of the erector spinae. It consists of three groups of overlying relays namely iliocostalis lumborum, iliocostalis thoracis and iliocostalis cervicis.

Iliocostalis lumborum. It has the same origin as erector spinae and is inserted by a flattened tendon into the lower part of the ridge on the angle of the lower six or seven ribs.

Nerve supply. It is supplied by the dorsal rami of the lower thoracic and upper lumbar nerves.

Actions. It is the extensor and lateral flexor of the vertebral column.

Iliocostalis thoracis. It arises from the upper border of the ridge on the angles of the lower six ribs and is inserted into the upper border of the ridge on the angles of the upper six ribs and into the back of the transverse process of the seventh cervical vertebra.

Nerve supply. It is supplied by the dorsal rami of the upper thoracic and lower cervical nerves.

Actions. Same as above.

Iliocostalis cervicis. It takes its origin from the angles of the third to the sixth ribs medial to the insertion of the iliocostalis thoracis and gains its insertion into the posterior tubercles of the transverse processes of the fourth, fifth and sixth cervical vertebra.

Nerve supply. It is supplied by the dorsal rami of the cervical and thoracic spinal nerves.

Actions. Same as iliocostalis lumborum.

Interspinales. They form short muscular fasciculi which are arranged in pairs, one on each side of the interspinous ligament stretching between two contiguous vertebrae. Each pair is attached to the tip of the spine above and connects the tip of the spine below, the interspinous ligament intervening. In the cervical region they are well-developed, in the thoracic and lumbar regions they are less well-formed.

In the cervical region there are six interspinales, the first between the second and the third cervical spines and last between the seventh cervical and first thoracic spines In the lumbar region there are four interspinales, the first between the first and second lumbar spines, and the last between the fourth and the fifth lumbar spines In the thoracic region there may be three interspinales, one between the first and the second thoracic spines, one between the second and the third thoracic spines and the third between the eleventh and the twelfth thoracic spines.

Nerve supply. They are supplied by the dorsal rami of the zonal spinal nerves.

Actions. They maintain security between two vertebrae and act as postural muscles

Transversospinalis. This forms a group of muscles which extends upwards and medially from the transverse processes to the spines of the vertebra above. They consist of the following:

Semispinalis thoracis.
Semispinalis cervicis.
Semispinalis capitis.

Semispinalis thoracis. It arises by a series of small tendons which extend from the transverse processes of the tenth to the sixth thoracic vertebrae and is inserted by tendons into the spines of the upper four thoracic and lower two cervical vertebrae.

Nerve supply. It is supplied by the dorsal rami of the cervical and thoracic nerves

Actions. It extends the thoracic and cervical parts of the vertebral column and cause them to rotate towards the opposite side.

Semispinalis cervicis. It arises by musculo-tendinous fibres from the transverse processes of the upper six thoracic vertebrae and gains its insertion into the spines of fifth to second cervical vertebrae.

Nerve supply and actions. Same as above.

Semispinalis capitis. This is a thick muscle on the back of the neck and forms an important landmark in that its fibres are vertical in direction, its medial border is free, it is pierced by the greater occipital nerve, it forms a part of the floor of the posterior triangle, it roofs in the sub-occipital triangle, it is crossed superficially and obliquely by the spelnius from above downwards and laterally and that both in front and behind, there is an arterial anastomosis.

It takes its origin from the transverse processes from the upper thoracic vertebrae and from the articular processes of the lower cervical vertebrae. It ascends vertically upwards and is inserted into the occipital bone between the superior and inferior nuchal lines medial to obliquus capitis superior.

Nerve supply. It is supplied by the posterior primary rami of the upper thoracic and cervical nerves.

Actions. Acting together it extends the head on the trunk; acting singly it flexes the head on the same side and rotates it to the opposite side as in turning the face sidewards.

Arterial anastomosis on the semispinalis capitis. On its *dorsal aspect* the descending branch of the superficial division of the occipital artery anastomoses with the ascending branch of the deep division of the occipital artery and the anasto-

mosing loop intervenes between the semispinalis capitis et cervicis. The above anastomosis establishes collateral circulation between the external carotid and the subclavian arteries.

Intertransversarii. As the name implies the intertransversarii muscles extend between the transverse processes of two adjacent vertebrae. They are well-developed in the cervical and lumbar regions but less so in the thoracic region.

In the cervical region there are seven intertransversarii muscles and each extends between the transverse processes of two adjacent vertebrae commencing from the transverse process of the first cervical to the transverse process of the first thoracic vertebrae. In this region each muscle consists of anterior and posterior slips demarcated by the passage of the ventral ramus of the cervical spinal nerve which intervenes between the two. The posterior intertransverse muscle is further divisible into medial and lateral portions; the medial portions are supplied by the dorsal rami while the lateral portions are supplied by the ventral rami of the cervical spinal nerves.

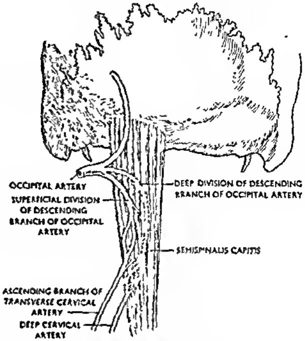


Fig. 503. *The insertion of semispinalis capitis with the arterial anastomosis on its surfaces.*

In the thoracic region there are only three intertransverse muscles which remain unsplit to form single muscles and the first extends between the transverse processes of the tenth and eleventh thoracic vertebrae and the last between the twelfth thoracic and the first lumbar vertebrae.

In the lumbar region these muscles are also well-developed and each muscle consists of two parts, medial and lateral. The medial intertransverse muscle extends from the accessory process of one vertebra with the mamillary process of the succeeding vertebra. Each lateral intertransverse muscle extends between the costal elements of two adjacent vertebrae and also extends from the accessory process to the transverse process.

Nerve supply. The intertransverse muscles of the thoracic region, the medial intertransverse muscles of the lumbar region and the medial parts of the posterior intertransverse muscles are supplied by the dorsal rami of the zonal spinal nerves while the others are supplied by the ventral rami.

Actions. They act in association with the long muscles and are concerned in steadying the vertebrae during the movement of the vertebral column as a whole.

Multifidus. It is a thick, strong muscle which consists of numerous musculo-tendinous fasciculi and extends from the sacral region to the level of the second cervical spine and fills up the gutter between the spines and the transverse processes. In the sacral region it arises from the walls of the cave produced by the origin of the erector spinae, from the dorsal sacroiliac ligaments and from the medial surface of the posterior superior iliac spine. In the lumbar region it arises from the mamillary processes, in the thoracic region from the dorsal aspects of all the transverse processes and in the cervical region, it arises from the articular pillars of the lower four cervical vertebrae. The musculo-tendinous fasciculi pass upwards and medially and are inserted into the spine or spines of the vertebrae above in the followiog ways: The longer superficial fasciculi from its origin from a particular vertebra ascend

upwards for their insertion to the whole length of the spine of the third or the fourth vertebra above; the intermediate fasciculi are inserted to the spine of the second or the third vertebra above while the deepest fasciculi are shortest ones which extend between two contiguous vertebrae.

Nerve supply. It is supplied by the dorsal rami of the spinal nerves.

Actions. It is the extensor, lateral flexor and rotator of the vertebral column.

Rotatores. They are the deepest group of muscles and are situated beneath the multifidus. They are only well-developed in the thoracic region where they form eleven pairs of muscles. In the cervical and lumbar regions they are ill-defined and less conspicuous.

ROTATORES THORACIS. They consist of eleven pairs of short, quadrilateral-shaped muscles. Each muscle arises from the upper and posterior aspects of the transverse process of one vertebra and is inserted into the lower border and lateral surface of the lamina of the next vertebra above. The first rotator thoracis extends between the first and the second thoracic vertebrae while the last one extends between the eleventh and the twelfth thoracic vertebrae.

Nerve supply. They are supplied by the dorsal rami of the zonal spinal nerves.

Actions. Same as above.

Sub-occipital triangle. It is a small intermuscular space which is intervened between the squamous part of the occipital bone and the posterior arch of the atlas.

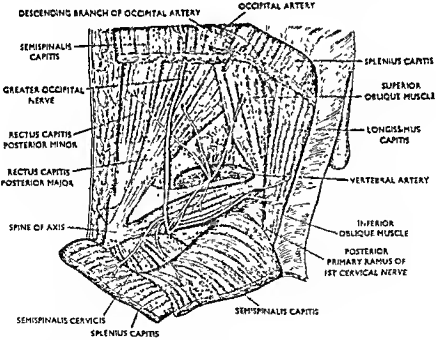


Fig. 504. The muscles of the right sub-occipital triangle with the structures contained within it. The veins have been removed.

Boundary. Above and laterally it is bounded by the obliquus capitis superior, below and laterally by the obliquus capitis inferior and medially by the rectus capitis posterior major et minor. Its roof is formed by the semispinalis capitis and the floor by the posterior atlanto-occipital membrane and the posterior arch of the atlas.

Contents.

(*a*) Third part of the vertebral artery.
(*b*) Vertebral vein. } Contents of the floor.
(*c*) Sub-occipital nerve.
(*d*) Greater occipital nerve — crosses the infero-medial angle.

Obliquus capitis superior. It is triangular in shape with its base directed upwards and the apex downwards. It takes origin by its apex from the upper surface of the transverse process of the atlas and passing upwards, backwards and laterally it is inserted into the occipital bone in between the superior and inferior nuchal lines lateral to the semispinalis capitis.

Actions. It flexes the head backwards and sidewards.

Obliqnus capitis inferior. It arises from the lateral aspect of the spine of the axis and running upwards, forwards and laterally it is inserted into the posterior inferior part of the transverse process of the atlas.

Action. It rotates the head to the same side.

Rectus capitis posterior major. It arises from the spine of the second cervical vertebra and is inserted into the occipital bone into the inferior nuchal line in its lateral part and to the bone below it.

Actions. It extends the head on the trunk and rotates it to the same side.

Rectus capitis posterior minor. It takes its origin by a pointed tendon from the tubercle on the posterior arch of the atlas (spinous tubercle) and ascending upwards it is inserted into the medial part of the inferior nuchal line and to the portion of the bone below it.

Nerve supply of the sub-occipital muscles. All the sub-occipital muscles, namely, obliquus capitis superior, obliquus capitis inferior and the rectus capitis posterior major et minor are supplied by the sub-occipital or the first cervical nerve through its posterior ramus.

Action. It extends the head backwards.

SCALENEI MUSCLES

Scalenus anterior muscle. The scalenus anterior muscle lies deeply at the side of the neck and arises from the anterior tubercles of the transverse processes of the third, fourth, fifth and sixth cervical vertebrae and the muscular fibres descend downwards to the root of the neck where they form a small tendon which is inserted into the scalene tubercle on the inner border of the first rib and also into the ridge on the upper surface of the rib.

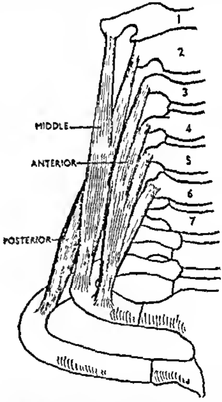


Fig. 505. The scalene muscles on the right side. The scalenus minimus is not shown.
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Relations.

Anteriorly.

1. The suprascapular vessels cross it transversely behind the clavicle.
2. The transverse cervical vessels cross it transversely in its upper part.

3. The ascending cervical branch of the inferior thyroid artery ascends upwards in front of it close to its origin and separates it from the longus capitis muscle.
4. The phrenic nerve crosses it obliquely from lateral to medial side.
5. It is covered by the prevertebral layer of the deep cervical fascia and is overlapped medially by the sternomastoid and the carotid sheath.
6. Its lower part lies under cover of the clavicle and the subclavius muscle.
7. The subclavian vein crosses it transversely just before its termination.

Posteriorly.

1. The subclavian artery crosses from medial to lateral side.
2. The scalenus medius muscle is separated from it by the nerves of the brachial plexus.

Medially and inferiorly.

1. Medially and inferiorly it is separated from the lower oblique part of the longus cervicis muscle by a triangular gap, *the scaleno-vertebral triangle,* which contains the vertebral artery with its vein, inferior thyroid artery, sympathetic trunk, inferior cervical ganglion, and on the left side, the thoracic duct in addition.

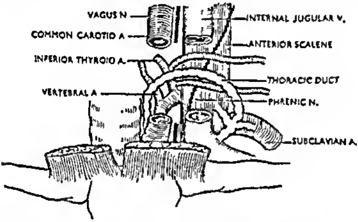

Fig. 506. Some relations in front of the scalenus anterior muscle on the left side.
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Nerve supply. It is supplied by branches of the anterior primary rami of the fourth, fifth and the sixth cervical nerves.

Scalenus medius. It arises from the front of the posterior tubercles of the transverse processes of the lower six cervical vertebrae and descending downwards it is inserted into the upper surface of the first rib between its tubercle and the groove for the subclavian artery.

Nerve supply. It is supplied by the anterior primary rami of the cervical nerves.

Scalenus posterior. It is the smallest and the deepest of all the scaleni muscles and it arises from the posterior tubercles of the fourth, fifth and sixth cervical vertebrae. It forms a delicate tendon which is inserted into the outer surface of the second rib behind the tubercle for the attachment of the serratus anterior muscle.

Nerve supply. It is supplied by anterior primary rami of sixth, seventh and eighth cervical nerves.

Actions of Scaleni. Acting from below they are lateral flexor of the neck to the same side, acting from above they elevate the rib or ribs to which they are inserted.

THE PREVERTEBRAL MUSCLES

The prevertebral muscles occupy the prevertebral region of the neck and are covered by the prevertebral layer of the deep cervical fascia. The following structures will be found in the prevertebral region.

1. Prevertebral muscles.
   (a) Longus capitis.
   (b) Longus cervicis.
   (c) Rectus capitis anterior.
   (d) Rectus capitis lateralis.
2. Cervical nerves.
3. Vertebral artery.

Longus capitis. It arises from the anterior tubercles of the second, third,

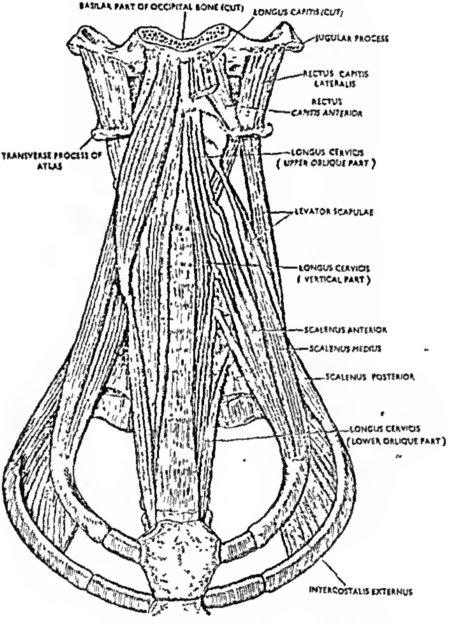


Fig. 507. The prevertebral and the scalene muscles.

fourth and fifth cervical vertebrae and its fibres ascend upwards to be inserted into the basilar part of the occipital bone on either side of the pharyngeal tubercle.

Actions. It causes flexion of the head and the neck and it also causes rotation of both the head and the neck.

Nerve supply. It is supplied by branches from the anterior primary rami of the first, second and the third cervical nerves.

Longus colli (cervicis). It consists of upper and lower oblique portions and an intermediate vertical portion.

The upper oblique portion arises from the anterior tubercles of the third, fourth and the fifth cervical vertebrae and ascending upwards and medially is inserted on the anterolateral part of the anterior tubercle of the atlas.

The lower oblique portion arises from the sides of the bodies of the upper two or three thoracic vertebrae and ascending upwards and laterally is inserted on the anterior tubercles of the transverse processes of the fifth and sixth cervical vertebrae.

The intermediate vertical part arises from the bodies of the lower cervical and upper thoracic vertebrae on either side of the median plane and ascending vertically upwards is inserted into the bodies of the upper cervical vertebrae. Its lateral margin is blended with the upper and lower oblique portions.

Actions. Same as longus capitis.

Nerve supply. It is supplied by the anterior primary rami of the third, fourth, fifth, sixth, seventh and eighth cervical nerves.

Rectus capitis anterior. It is a short muscle and arises from the front of the lateral mass of the atlas and is inserted into the basilar part of the occipital bone just in front of the anterior end of the occipital condyle.

Action. It is the flexor of the head.

Nerve supply. It is supplied by the branches from the loop of communication between the first and the second cervical nerves.

Rectus capitis lateralis. It does not belong to the prevertebral group of muscles but it will be convenient to deal with this muscle along with the prevertebral group of muscles.

It arises from the upper surface of the transverse process of the atlas and ascending vertically upwards is inserted into the inferior surface of the jugular process of the occipital bone.

Action. It flexes the head sidewards.

Nerve supply. Same as above.

SUPERIOR EXTREMITY

THE MUSCLES AND FASCIAE OF PECTORAL REGION

Superficial fascia. This is the general investing fascia containing fat in this region and lies immediately beneath the skin. Just beneath it there lies the deep fascia which is membranous in character and closely invests the pectoralis major muscle. The superficial fascia of the neck, which contains some thin muscle fibres in this region (platysma) and the superficial fascia of the abdomen below, are continuous with it. It is adherent to the skin at different places and sends out several deep processes which enclose the mammary gland in case of female. The processes that connect it with the skin and the fibrous septa that enclose the different lobes of the mammary gland together constitute the *suspensory ligament of the breast* or *the ligament of Cooper*. The cutaneous vessels and nerves ramify in the superficial fascia.

Deep fascia. The deep fascia of the pectoral region is known as the *pectoral fascia* and covers the same muscle. It is attached above to the clavicle and is

ontinuous below with the fibrous sheath of the rectus abdominis. *Medially* it is ttached to the front of the sternum opposite the median plane. *Laterally* along he lower border of the pectoralis major it is continuous with the axillary fascia. Opposite the delto-pectoral triangle, which is an intermuscular hollow immediately elow the lateral one-third of the clavicle, it sends out a deep process which separates he deltoid muscle from the pectoralis major and is attached posteriorly to the lavipectoral fascia.

Deltoido-pectoral triangle or infra-clavicular fossa. It is a triangular interval between the clavicular origin of the pectoralis major and the clavicular origin of the deltoid muscles.

Boundary. It is bounded *below* and *medially* by the clavicular origin of the pectoralis major muscle, and *above* and *laterally* by the clavicular origin of the deltoid muscle. The *base* is formed by the clavicle between the origins of the former two muscles, the *apex* is formed by the union of the pectoralis major and the deltoid muscles, the *floor* is formed by the clavipectoral fascia and it is roofed by the skin and the superficial and the deep fasciae.

Contents:

(1) Terminal portion of the cephalic vein.
(2) Deltoid and acromial branches of the thorcoacromial (acromiothoracic) artery.
(3) Delto-pectoral lymph gland.

Pectoralis major. It is a large fan-shaped muscle which covers the front of the anterior chest wall on each side and is the most superficial muscle in the pectoral region. It connects the trunk with the arm bone and together with the pectoralis minor it forms the anterior axillary fold.

Developmentally it is derived from the upper limb myotome and of the three primitive layers of the body wall it belongs to the outermost layer in common with the obliquus externus abdominis.

Origin. It consists of clavicular, sternocostal and abdominal portions. (*a*) The *clavicular portion* takes its origin from the anterior surface of the medial half of the clavicle. (*b*) The *sternocostal portion* takes its origin from the lateral part of the anterior surface of the manubrium and the body of the sternum, from the cartilages of the second to the sixth ribs and from the anterior intercostal membranes. (*c*) The *abdominal portion* takes its origin from the aponeurosis of the obliquus externus abdominis.

Insertion. The muscle ends in a flat tendon about 2 inches long which is inserted into the lateral lip of the bicipital groove or the intertubercular sulcus of the humerus as follows:

The *clavicular fibres* pass almost horizontally lateralwards and form a distinct group which remains separated, in most of its course, from the rest of the muscle by a fissure and are inserted by a tendon into the lateral lip of the bicipital groove, anterior margin of the deltoid tuberosity and into the deep fascia of the arm. The *sterno-costal and abdominal fibres* pass upwards and laterally, the lower fibres being more oblique than the upper ones, and form a tendon which is twisted on itself so as to form two lamellae, which are inserted behind the clavicular fibres. Thus the tendon of insertion of the pectoralis major is a *trilaminar tendon* consisting of anterior, intermediate and posterior lamellae. The anterior lamella is formed by the clavicular fibres. The fibres from the manubrium sterni form the intermediate lamella which is inserted behind the anterior lamella while the rest of the sterno-costal and the abdominal fibres form the posterior lamella which turns upwards behind the intermediate lamella and ascends on the lateral lip on a higher level than the preceding fibres and finally becomes continuous with the capsule of the shoulder joint. Thus the tendon of insertion of the sterno-costal and abdominal fibres resembles a fish-hook in appearance, the shorter limb of the hook represents the intermediate lamella in relation to the anterior lamella formed by

clavicular fibres and longer limb of the hook representing the posterior lamella. Due to this twisting of the sterno-costal and abdominal fibres the lowest fibres of origin gain highest position in insertion. Three fibrous expansions pass from the tendon of insertion—one roofs in the intertubercular sulcus, one covers the floor of the intertubercular sulcus and the third is continuous with the capsule of the shoulder joint.

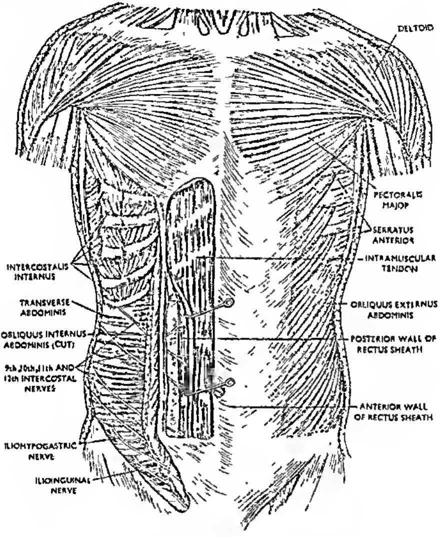


Fig. 508. The superficial flat muscles of the chest wall and abdomen together with the opened-up rectus sheath to show the rectus abdominis muscle and its nerve supply.

Nerve supply. It is supplied by lateral and medial pectoral nerves (C 5 to 8, T1).

Actions. It is the flexor, adductor and the medial rotator of the shoulder joint. When the arms are fixed its sternocostal fibres act as a climbing muscle by drawing the trunk upwards and forwards. The sternocostal head is a powerful adjuvent in extension of the shoulder when it is extended against resistance.

Clavi-pectoral fascia The clavi-pectoral fascia is a membranous sheet of fascia which extends from the cartilage of the first rib medially to the coracoid . . laterally and bridges over the triangular interval between the inferior rface of the clavicle above and the pectoralis minor muscle below.

Attachment and distribution:

Laterally it is attached to the root of the coracoid process of the scapula.

Medially it is attached to the first rib and is continuous with the fascia covering the first and second intercostal spaces.

Superiorly it splits into two lamellae which enclose the subclavius muscle and are fixed to the margins of the subclavian groove on the inferior surface of the clavicle, the deep lamella being continuous with the deep cervical fascia.

Inferiorly it splits to enclose the pectoralis minor muscle and at the lower border of the same the two layers reunite to form a single layer which unites with the pectoral fascia and then is continuous with the axillary fascia forming the *suspensory ligament of the axilla.*

Characteristic feature. It is not uniform in its character throughout the entire extent. Thus the upper part of the fascia immediately below the subclavius muscle and extending from the cartilage of the first rib to the root of the coracoid process of the scapula is very thick and strong and is known as the *costo-coracoid ligament.* At a lower level it is very thin and delicate.

Relation. It is covered superficially by the clavicular fibres of the pectoralis major. Deep to it are the first portion of the axillary artery and the axillary vein and the cords of the brachial plexus of nerves. It is pierced by the (1) *Cephalic vein,* (2) *the acromiothoracic vessels,* (3) *the lateral pectoral nerve* and (4) *the lymphatics from the upper and inner quadrant of the breast.*

The acromio-thoracic artery, immediately after piercing it, divides into *clavicular, pectoral, deltoid* and the *acromial branches* which spread out in all directions over this membrane to reach their destination. The medial pectoral nerve passes deep to the membrane to reach the pectoralis minor muscle and then piercing this muscle enters into the pectoralis major.

N.B.—Any collection of pus in between the pectoralis major and the pectoralis minor or the collection of pus superficial to the clavipectoral fascia tends to gravitate downwards and laterally and point along the anterior fold of the axilla because it is in this situation that the clavi-pectoral fascia blends with the pectoral fascia and unless the clavipectoral fascia is destroyed it cannot point in the axilla. It may also point along the intermuscular furrow between the deltoid and the pectoralis major.

Collection of pus beneath the clavi-pectoral fascia may take the course as follows: Taking the course of the clavi-pectoral fascia it may pass into the axilla under the axillary fascia and point in the axilla. The pus cannot go posteriorly because the serratus anterior is inserted into the vertebral border of the scapula. Its progress anteriorly is prevented by the clavi-pectoral fascia. It cannot go medially because of the thoracic wall. If early drainage is not performed through the axilla the pus may follow the axillary and the subclavian vessels and may point in the neck under the deep cervical fascia. Taking the course of the latter it may pass down into the mediastinum of the thoracic cavity. The pus may however take the course of axillary vessels and the nerves downwards into the arm

Pectoralis minor. It is a small flat triangular muscle which lies beneath the pectoralis major and connects the upper part of the trunk with the coracoid process of the scapula. It is also derived from the upper limb myotome and is a member of the outermost layer of the three primitive sheets of musculature of the body wall.

Origin It arises from the outer surface of the third, fourth and the fifth ribs close to their costal cartilages and from the fascia covering the external intercostal muscle.

Insertion. It is inserted into the medial border and upper surface of the coracoid process of the scapula.

Nerve supply. It is supplied by the medial and lateral pectoral nerves (C 7 and 8, T 1).

Actions. Acting with the levator scapulae and rhomboids it depresses the point of the shoulder. It is one of the inspiratory muscles and elevates the upper ribs when the arm is fixed.

Subclavius. It is a small elongated muscle which lies horizontally underneath the clavicle, hence the name subclavius, and connects the trunk with the clavicle.

Origin. It arises by tendinous fibres from the upper surface of the first rib and the adjoining portion of the first costal cartilage and passes horizontally lateralwards towards its insertion.

Insertion. It is inserted by fleshy fibres into the subclavian groove on the inferior surface of the middle two-thirds of the clavicle.

Nerve supply. It is supplied by the "nerve to the subclavius" a branch from the upper trunk of the brachial plexus (C 5 and 6).

Action. When the first rib is fixed it depresses the clavicle and draws it inwards and thus fixes the sternal end of the clavicle at the sternoclavicular joint. When the shoulder girdle is fixed it assists forced inspiration by elevating the first rib.

BACK

The region of the back falls partly under the domain of the superior extremity and partly under the head and neck and in treating this the students of the superior extremity must work in conjunction with the students of the head and neck.

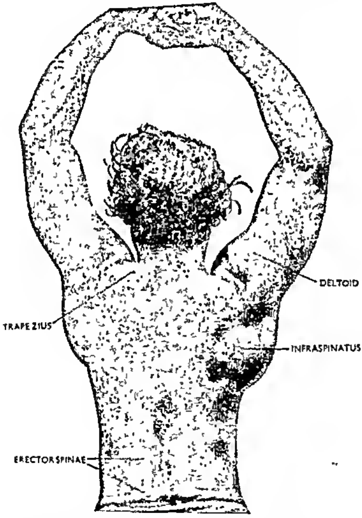


Fig. 509. The muscles of the back and upper arm (seen from behind) in a muscular body in active contraction. "Biswa Sree" Monotosh Roy is seen in this poise.

Superficial fascia. The superficial fascia of the back forms the general investing fascia beneath the skin and is specially thickened in this region. It is continuous with the superficial fascia of the adjoining regions and contains fat in its meshes.

Deep fascia. It is a dense, membranous layer of fascia which covers the muscles of the back and is continuous above with the deep fascia of the neck. Below it is attached to the iliac crest. Medially, in the thoracic and lumbar regions, it is attached to the vertebral spines and to the supraspinous ligaments.

Laterally, in the thoracic region, it is attached to the spine and the acromion of the scapula.

Trapezius. It is a flat, large, triangular and most superficial muscle in the back region and its wide base corresponds to the median plane while its apex converges towards the point of the shoulder. When the two trapezius muscles, one on each side, are seen together they resemble a geometrical trapezium in form and hence the muscle gets its name "trapezius".

Origin. It arises from the external occipital protuberance, from the medial one-third of the superior nuchal line, from the ligamentum nuchae, from the spines of the seventh cervical and all the thoracic vertebrae and from the supraspinous ligaments.

Insertion. Its upper fibres descend downwards and laterally and are inserted into the posterior border of the lateral one-third of the clavicle; the lower fibres pass upwards and laterally, form a tendon which glides over the smooth triangular area at the root of the spine of the scapula and is inserted into the tubercle lateral to the apex of the smooth triangular area. The middle fibres pass transversely and are inserted into the medial margin of the acromion and the upper lip of the spine of the scapula.

Nerve supply. It is supplied by the accessory nerve (spinal root) and by the branches from the third and fourth cervical nerves. The accessory nerve is the true motor nerve and the cervical nerves are proprioceptive for the trapezius. These nerves enter the deep surface of muscle and traverse through the posterior triangle en route to trapezius.

Action. When the head is fixed, the trapezius, acting with the levator scapulae, raises the scapula and the point of the shoulder. Acting with the rhomboids, it draws the scapula towards median plane; acting with serratus anterior, it rotates the scapula in a forward direction and thus enables the arm to be raised above the shoulder; acting together, they draw the head and the neck backwards; acting singly, it draws the neck to the same side.

Latissimus dorsi. It is a large, triangular, flat and a superficial muscle on the back which is characterized by its extensive origin and narrow and thin tendon of insertion. As it is roughly triangular in shape it has a base, an apex and two borders, upper and lateral. Its base corresponds to its origin from the vertebral spines while its apex corresponds to its tendon of insertion.

Origin. The muscle takes its principal origin by its base and can be divisible into upper, middle and lower fibres. The upper fibres take origin by tendinous fibres from the spines of the lower six thoracic vertebrae and the corresponding supraspinous ligaments beneath the trapezius; its lower and middle fibres are aponeurotic and take their origin from the posterior lamella of the lumbar fascia and through this, the muscle is connected with the spines of all the lumbar and the sacral vertebrae and the iliac crest; by its lateral border it arises by tendinous fibres from the posterior part of the outer lip of the iliac crest lateral to the origin of the sacrospinalis and by fleshy slips, interdigitating with external oblique, from the outer surface of the lower three or four ribs; its upper border sometimes gains some slips of origin from the dorsal aspect of the inferior angle of the scapula.

Insertion. From the extensive origin the muscle fibres pass in different directions, the upper fibres passing transversely, the middle fibres obliquely upwards, and

the lower fibres vertically upwards. All these fibres converge to a ribbon-like flat tendon which is inserted into the bottom of the intertubercular sulcus of the humerus. Its tendon of insertion is from $1\frac{1}{2}$ inches to 2 inches in breadth and is as thin as a paper and extends to a higher level than the insertion of teres major muscle. The tendon of insertion is twisted upon itself so that the fibres which are lowest at its origin are highest at their insertion and the surfaces of the muscle, that is, anterior and posterior, are reversed at the insertion of the tendon. In its course upwards and laterally it winds round the teres major muscle and forms a greater part of the posterior *axillary fold*.

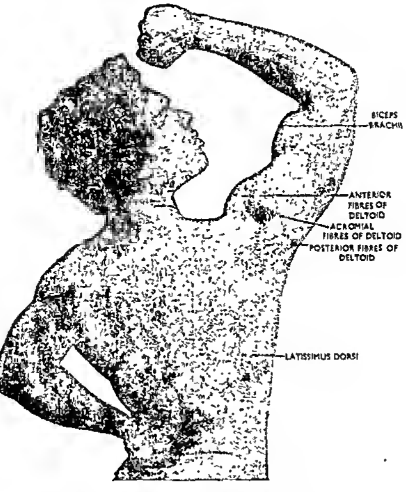


Fig. 510. The muscles of the upper arm and back (seen from an angle from behind) "Biswa Sree" Monotosh Roy is seen in this poise.

Nerve supply. It is supplied by the nerve to the latissimus dorsi, a branch from the posterior cord of the brachial plexus and derives its fibres from the sixth, seventh and eighth cervical nerves.

Actions. Acting from below it draws the humerus backwards (extensor of the shoulder joint). When the arm is abducted it draws it to the side of the chest wall and rotates it medially (adductor and medial rotator of the shoulder joint); if the arms are fixed above the head, it draws the trunk upwards and forwards as in climbing; acting from above it draws the lower ribs upwards and helps in forced expiration and other violent expiratory efforts such as coughing and sneezing.

Triangle of auscultation. It is a triangular space bounded above by the lateral border of the trapezius, below by the upper border of the latissimus dorsi

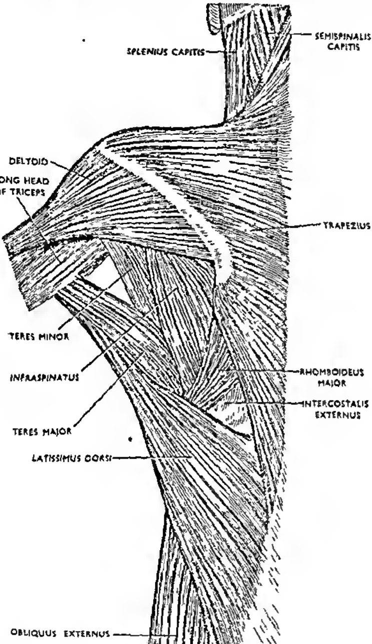


Fig. 511. The superficial muscles of the back. Left side.

and laterally by the vertebral border of the scapula; its floor is formed by the seventh rib and the sixth and seventh intercostal spaces which are covered in this situation by a fascial sheet which connects the latissimus dorsi and the rhomboids. The

Deltoid. It is a thick, triangular multipennate muscle which covers the shoulder joint from in front, behind, above and from the lateral side, thus giving a rounded contour to the shoulder.

Origin. Its origin may be divided into three portions as anterior or clavicular, middle or acromial and a posterior or spinous portion. The *anterior* or *clavicular portion* arises from the anterior border and the adjoining upper surface of the lateral one-third of the clavicle; the *acromial* or *middle portion* arises from the lateral margin and the adjoining upper surface of the acromion; and the *posterior* or *spinous portion* arises from the lower lip of the crest of the spine of the scapula as far as the triangular area at the apex of the spine and from the fascia of the infraspinatus muscle.

Insertion. For the different origins the fibres converge to a thick tendon which is inserted into the "V"-shaped impression on the upper part of the antero-lateral surface of the shaft of the humerus.

Structurally the deltoid muscle consists of very coarse fibres, particularly in its middle or acromial portion. Its anterior portion consists of parallel fibres whereas its most posterior portion has a membranous origin, fibres from which converge to the tendon of insertion. The fibres of its middle portion are arranged like a multipennate muscle. The muscle fibres in this portion are obliquely arranged like that of several bi-pennate muscles housed together; usually four intramuscular septa descend from the lateral margin of the acromion, and from the walls of two adjacent septa the muscle fibres pass obliquely like a bi-pennate muscle to converge to an intermediate tendinous septum ascending upwards from the tendon of insertion. Thus there are three ascending septa each of which ascends upwards to intervene between two adjacent descending septa from the acromion. This penniform arrangement adds great strength to the muscle (middle portion), for it has to work against gravity to lift up the arm. (Axillary Nerve)

Nerve supply. It is supplied by the circumflex nerve (C 5 and 6) from the posterior cord of the brachial plexus.

Relation. The deltoid muscle in its course to its insertion is spread out over the greater tuberosity of the humerus and thus forms the rounded prominence of the shoulder. It is superficial in its entire extent and is covered by the skin, superficial fascia and the deep fascia. Anteriorly it is separated from the pectoralis major by a groove which contains the cephalic vein and the deltoid branch of the acromiothoracic artery. When the deltoid muscle is reflected its deep surface is found to be related with the following structures:

(i) Coracoid process of the scapula together with the structures associated with it, namely conjoined tendon of origin of coracobrachialis and the short head of the biceps brachi, pectoralis minor and the coraco-acromial ligament.

(ii) The greater and lesser tuberosity of the humerus and the structures attached to them, that is, the tendon of supraspinatus, infraspinatus, teres minor and the subscapularis. The tendinous fibres from these muscles form a continuous sheet of tendinous cuff which fuses with the capsular ligament of the shoulder joint and separates the ligament from the deltoid.

(iii) *Vessels.* (*a*) The *anterior humeral* and the *posterior humeral circumflex* arteries cross the corresponding aspect of the surgical neck of the humerus and anastomose with each other.
(*b*) The ascending branch of the anterior humeral circumflex artery ascends upwards in the bicipital groove.

(iv) *Nerve.* (*a*) The *circumflex nerve* accompanies the posterior humeral circumflex artery and divides into anterior and posterior branches. The anterior branch supplies the anterior part of the deltoid while the posterior division supplies a twig to the teres minor and then pierces the posterior part of the deltoid.

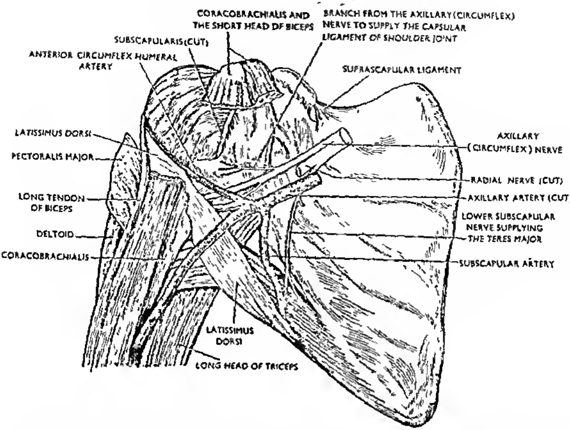


Fig. 513. The ventral aspect of the Scapulo-humeral region with the removal of the subscapularis and a part of the Coracobrachialis and the short head of biceps brachii. From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

(v) *Other structures.* (a) *Subacromial bursa.* It lies beneath the acromion process and intervenes between it and the supraspinatus tendon.
(b) Upper part of the anterolateral aspect of the shaft of the humerus.

Action. It is the abductor, flexor, extensor, and lateral and medial rotators of the shoulder joint. The deltoid works either in part or in whole to execute the above functions.

Acting with the pectoralis major its *anterior fibres* act as the flexor and medial rotator of the arm. Acting with the latissimus dorsi and the teres major its *posterior fibres* act as the extensor and lateral rotator of the arm. *While working as a whole* it is the true abductor of the shoulder joint. While abducting the arm it works jointly with the supraspinatus muscle and during this movement its anterior and posterior fibres work from the front and behind respectively so as to steady the humerus in its plane of movement and its middle fibres together with the supraspinatus work vigourously to raise the arm against gravity away from the trunk up to the level of the shoulder. Raising of the arm above the shoulder to bring the arm in line with the head is a movement of the shoulder girdle and is caused by serratus anterior and the trapezius; the deltoid and the supraspinatus now work as fixators.

Supraspinatus. It is a triangular muscle which occupies the supraspinous fossa of the scapula—hence the name 'supraspinatus' and lies under cover of the trapezius muscle.

Origin. It arises from the medial two-thirds of the supraspinous fossa, from the adjoining part of the upper surface of the spine and from the fascia supraspinous.

Insertion. From its origin the muscle passes laterally beneath the acromio-clavicular ligament and converges to a tendon which passes over the capsular liga-

ment of the shoulder joint and is inserted to the highest of the three impressions on the greater tuberosity of the humerus. As it passes over the capsular ligament it is intimately adherent to the same and is separated from the undersurface of the acromion by the subacromial bursa.

Nerve supply. It is supplied by the suprascapular nerve (C. 5, 6).

Action. Acting with deltoid it abducts the arm to bring it in line with the shoulder. It also helps in stabilising the head of the humerus in all other movements of the shoulder joint.

N.B.—With every movement of abduction within an arc of movement varying from 60° to 120° the supraspinatus tendon comes in contact with the undersurface of the acromion and there is friction between the two, and in order to minimise the friction, the sub-acromial bursa intervenes between them. With the advancing age, specially with those who have to undergo hard manual labour, this sub-acromial bursa undergoes attrition which exposes the supraspinatus tendon to injury in the form of repeated frictions with every movement of abduction. Repeated trauma in the form of friction leads to degenerative tendinitis of the supraspinatus tendon which becomes softned and slightest trauma may cause complete rupture of the same. Calcification supervenes in the degenerated tendon and the degenerative changes may spread to the neighbouring tendons and the capsular ligament of the shoulder joint. In supraspinatus tendinitis there is a painful arc in the movement of abduction which ranges from 60° to 120° and outside this range there is total relief of pain, that is, when supraspinatus tendon undergoes friction with the acromion there is pain and when it recedes from the same there is relief of pain. Moreover, there is a local tender spot opposite the top of the greater tuberosity of the humerus. In rupture of the supraspinatus tendon there is complete loss of the movement of abduction and this explains that the movement of abduction is carried out by the conjoined action of the deltoid and the supraspinatus and none of them can act singly to effect the movement..

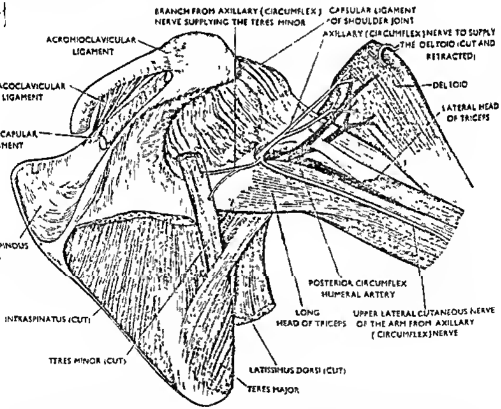


Fig. 514. The dorsal aspect of the scapulo-humeral region. The supraspinatus, a part of the infraspinatus, teres major, latissimus dorsi and the deltoid have been removed. From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

Teres Major. It arises from the oval muscular impression on the dorsal aspect of the scapula above the inferior angle and adjoining the axillary border and from the intermuscular septa between it and the teres minor, and between them and the

infraspinatus. It forms a flattened muscular belly which ascends upwards and laterally and forms a tendon which is inserted into the medial lip of the bicipital groove. Its tendon of insertion is overlapped by the tendon of the latissimus dorsi with which it is blended.

Nerve supply. It is supplied by a branch from the lower subscapular nerve (C. 5 and 6).

Actions. Its main action is to adduct the arm. Together with the latissimus dorsi it extends the arm. It also helps in stabilising the head of the humerus during various movements of the arm.

Triangular and quadrangular spaces. The teres major muscle, as it inclines upwards and laterally from the dorsal aspect of the scapula, *encloses* a triangular area between the scapula and the humerus ; the long head of the triceps which descends downwards and laterally from the infraglenoid tuberosity subdivides this triangular gap into a *quadrilateral* and a *triangular area*. The long head of the triceps in its course downwards and laterally passes behind the teres major and in front of the teres minor. It joins the medial head of the triceps in the upper part of the arm at an

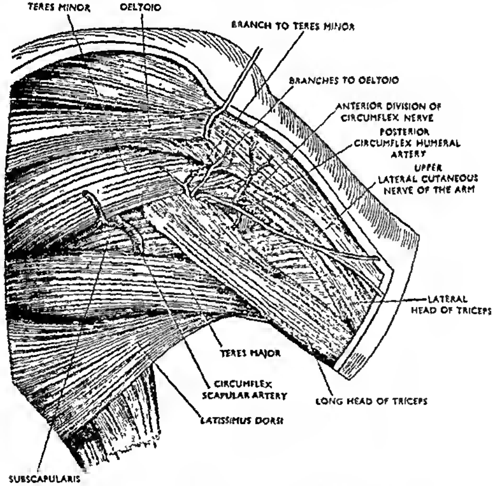


Fig. 515. The quadrangular and the triangular spaces on the right side. Seen from behind. From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

angle and encloses a triangular space between it and the shaft of the humerus below the lower border of the teres major. Thus two triangular areas are formed in this situation, the former is known as the *upper triangular area* and the latter is known as the *lower triangular area*.

Quadrangular or Quadrilateral Space. It is bounded above and in front by the subscapularis, and above and behind by the teres minor, below by the teres major, laterally by the surgical neck of the humerus and medially by the long head of the triceps. The posterior humeral circumflex vessels and the circumflex nerve traverse this space.

Upper Triangular Space. It is bounded above by the teres minor, below by the teres major and laterally by the long head of the triceps. It contains the scapular circumflex vessels.

Lower Triangular Space. It is bounded above by the teres major and the latissimus dorsi, laterally by the shaft of the humerus and medially by the long head of the triceps. The radial nerve and the profunda vessels as they pass to the back of the arm will be found in this space and also a portion of the brachial artery will be viewed from this window.

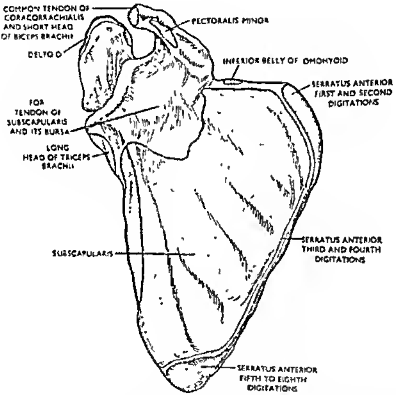


Fig. 516. The muscular attachments on the ventral aspect of the right scapula.

Subscapularis. It is a large triangular muscle which occupies the costal surface or the sub-scapular fossa of the scapula—hence the name subscapularis, and froms the greater part of the posterior wall of the axilla.

Origin. It takes its origin from the medial two-thirds of the subscapular fossa including the vertical grooved area adjoining the axillary border of the scapula, from the intramuscular tendons attached to the ridges in the subscapular fossa and from the intermuscular septum between it and the long head of the triceps brachii and the teres major.

Insertion. From its origin the muscle fibres converge to its tendon which passes laterally through a shallow groove on the ventral aspect of the neck of the scapula from which it is separated by a bursa communicating with the shoulder joint. It is inserted into the lesser tuberosity and to the capsule of the shoulder joint by tendinous

fibres and into the anterior part of the humerus below the lesser tuberosity by fleshy fibres. The attachment of fleshy fibres extends for about an inch and lies under cover of the common tendon of coracobrachialis and the short head of the biceps brachii.

Relation. Anteriorly, towards the vertebral border of the scapula, its lower portion is overlapped by the serratus anterior whereas opposite its insertion, it is crossed by the common tendon of coracobrachialis and the short head of the biceps brachii, and medial to the coracobrachialis, it is crossed by the branches from the cords of the brachial plexus of nerves and the axillary and the subscapular vessels. Its posterior surface is in relation to the subscapular fossa, neck of the scapula and the capsular ligament of the shoulder joint. Its lower border comes into contact with the teres major and the latissimus dorsi.

Nerve supply. It is supplied by upper and lower subscapular nerves (C. 5 and 6) from the posterior cord of the brachial plexus.

Infraspinatus. It arises from the medial 2/3 of the infraspinous fossa of the scapula and from the infraspinous fascia. It soon forms a tendon which passes across the posterior part of the capsular ligament of the shoulder joint and is inserted into the greater tubercle of the humerus in between the supraspinatus and teres minor.

Nerve supply. It is supplied by the suprascapular nerve.

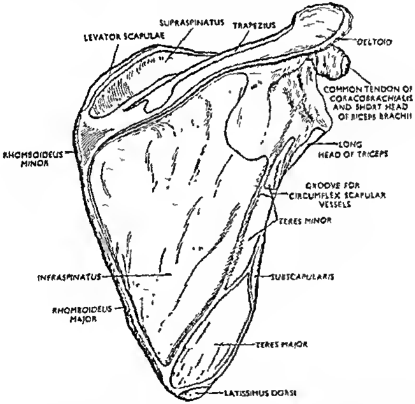


Fig. 517. The muscular attachments on the dorsal aspect of the right scapula.

Actions. In association with the teres minor it acts as a *lateral rotator of the arm.* Moreover, along with the other muscles of the shoulder joint (Supraspinatus, teres minor, subscapularis) it helps in stabilising the head of the humerus against the glenoid cavity in all movements of the shoulder joint.

Teres minor. It arises from the axillary border of the scapula adjoining the dorsal surface between the infraglenoid tuberosity and the teres major and also from the intermuscular septum between it and the infraspinatus and the teres major.

It is inserted into the lowest of the three impressions of the greater tubercle of the humerus and to a small extent to the adjoining surface of the shaft of the humerus. Its tendon of insertion lies on the posterinr aspect of the capsular ligament with which it is blended.

Nerve supply. It is supplied by a hranch from the posterior division of the circumflex nerve (C. 5).

Action. It is the ***lateral rotator*** of the arm, and when the arm is abducted at right angle to the trunk, together with the pectoralis major, it draws the arm horizontally forwards. It is also an ***adductor*** and helps in stabilising the head of the humerus in other movements of the shoulder joint.

FRONT OF THE ARM

The most conspicuous feature of the front of the arm is the fusiform muscular prominence caused by the biceps brachii. On either side of the biceps is a vertical groove which marks the position of the *intermuscular septa (lateral and medial)* and each is occupied by a vein, that on the medial side lodges the basilic vein, *brachial artery* and *the median nerve and that on the lateral side lodges the* cephalic vein. The muscular prominence behind the proximal half of the medial margin of the biceps in an abducted arm is caused by the coracobrachialis.

Deep fascia of the arm. The deep fascia of the arm is a tough membranous fascia which invests the muscles of the arm. It consists mainly of transverse fibres being thinner in front and thicker behind. On either side it gives out an intermuscular septum which separates the flexors from the extensor muscles. The ***lateral intermuscular septum*** is attached to the lateral supracondylar line and to the lateral border up to the insertion of the deltoid. It is pierced by the radial nerve and by the anterior descending branch of arteria profunda brachii. The medial intermuscular septum is attached to the medial supracondylar line and to the medial margin as far as the insertion of the coracobrachialis. At its proximal end it is pierced by the ulnar nerve and the ulnar collateral artery and close to the elbow joint by the posterior branch of supratrochlear artery. Superiorly the deep fascia is continuous with the axillary fascia and the fascia covering the pectoralis major and the deltoid. Inferiorly it is thickned in front of the elbow joint and receives an expansion from the bicipital aponeurosis and is continuous with the antebrachial fascia. On the medial side, opposite the middle of the arm, the deep fascia is pierced by the basilic vein and the medial cutaneous nerve of the arm and of the forearm. From the above distribution it is evident that the deep fascia together with the lateral and the medial intermuscular septa converts the arm into two osseo-aponeurotic compartments, anterior and posterior. The ***anterior osseo-aponeurotic compartment*** contains the flexor muscles while the posterior osseo-aponeurotic compartment lodges the extensor muscles.

Muscles of the front of the arm—

Coracobrachialis. It is a band-like muscle which extends from the tip of the coracoid process to the brachium or the arm and hence it is named 'coracobrachialis'. Although functionally unimportant it has interesting morphological and anatomical importance.

Origin. It arises from the tip of the coracoid process of the scapula in common with the tendinous short head of the biceps brachii and lies on the medial side of the latter tendon; it also arises by fleshy fibres from the medial aspect of the upper part of the common tendinous origin.

Insertion. From its origin it passes downwards in front of the subscapularis muscle to reach the arm and is inserted into the medial border of the humerus opposite the middle of the arm. Its insertion covers an area about one and a half inches in length and intervenes between the medial head of the triceps behind and the [illegible] in front.

Nerve supply. It is supplied by the musculocutaneous nerve of the arm and derives its fibres from seventh cervical nerve. C 7.

Action. It is the flexor and adductor of the shoulder joint.

Relation. In its course down to the arm it lies successively on the subscapularis, teres major, latissimus dorsi, medial head of the triceps and the medial aspect of the humerus. *Anteriorly* its upper part is covered by the pectoralis major muscle and opposite its insertion it is related to the brachial artery with its venae commitans and the median nerve. Medially it is related to the third part of axillary artery, upper part of the brachial artery and the median nerve. The median nerve crosses in front of the brachial artery opposite the insertion of coracobrachialis to gain the medial side of the artery. Laterally it is related to the biceps brachii and the brachialis. *The muscle is pierced by the musculocutaneous nerve.*

Anatomical Importance. The insertion of coracobrachialis bears some important anatomical landmark which deserves a special mention. (1) At this level the median nerve crosses the brachial artery from lateral to the medial side. (2) The ulnar nerve and the ulnar collateral artery pierce the medial intermuscular septum at this level. (3) The basilic vein pierces the deep fascia. (4) The upper limit of the medial intermuscular septum corresponds to this level. (5) Upper supratrochlear lymph glands lie at this level and (6) the medial cutaneous nerve of the forearm pierces the deep fascia.

Morphological Importance. In some animals the coracobrachialis consists of three heads of origin, two upper heads and a lower head. In man the lower head usually retrogresses but in some cases it may be present. The third head is usually associated with the presence of supracondylar process, a spur of bone of varying measurement which projects downwards and forwards from the anteromedial surface of the humerus about 5 cm. above the medial epicondyle. This supracondylar process when present is connected with the medial supracondylar ridge by a fibrous band (Ligament of Struthers) and forms a osseo-fibrous foramen (representing epitrochlear foramen of carnivores and some other mammals) in this situation through which the median nerve and the brachial artery pass. From the lower part of the fibrous band the pronator teres takes it origin while from its upper part the third head of coracobrachialis, when present, takes its origin. The musculocutaneous nerve is usually imprisoned in between its upper two heads.

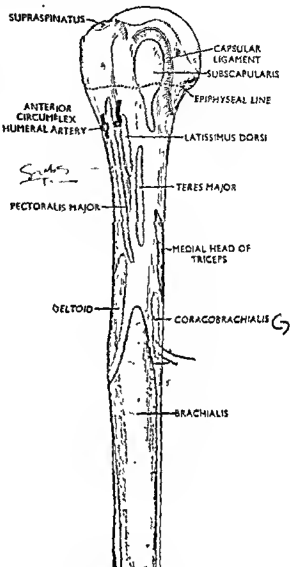


Fig. 518 The anterior view of the right humerus showing muscular and ligamentous attachments and some of the relations.

Biceps brachii. It is a long spindle-shaped muscle occupying the whole of the front of the arm. It has been so named because it has two heads of origin, a long and a short head

Origin. The long head begins as an elongated tendon which arises from the supraglenoid tubercle above the upper end of the glenoid cavity of the scapula and from the adjoining part of the glenoidal labrum; its tendon of origin being intracapsular, it traverses through the shoulder joint being invaginated by the synovial membrane and comes out of the joint through the opening in the capsular ligament above the intertubercular sulcus; and carrying a synovial sheath, it passes through the sulcus to the proximal part of the arm where it gives rise to an elongated muscular belly and soon joins with its short head. The short head arises by a thickened tendon from the tip of the coracoid process of the scapula in common with the coracobrachalis. It is succeeded by an elongated muscular belly which joins with the muscular belly from the long head and the two bellies form a fusiform muscle.

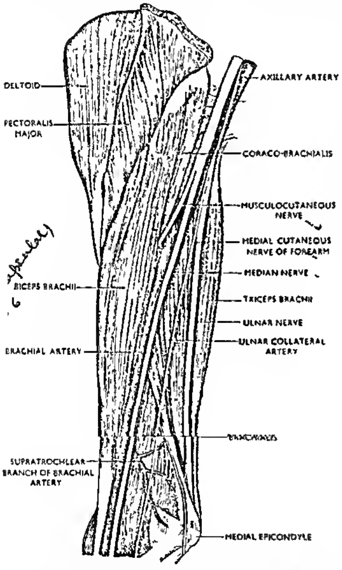


Fig. 519. The front and the medial aspects of the right arm. From the dissection hall, N. R. Sircar Medical College, Cal; with kind permission from the Prof. of Anatomy.

Insertion. Immediately above the elbow it forms a flattened tendon which dips into the cubital fossa and is inserted into the posterior rough portion of the radial tuberosity being separated from its anterior smooth portion by a bursa. As the tendon dips down to be inserted, it is twisted on itself so that its anterior surface looks lateralwards and at this point of twisting it sends out an aponeurotic expansion to the antebrachial fascia to form the bicipital aponeurosis which roofs in the cubital fossa and separates the brachial artery from the median cubital vein. The anterior portion of the tendon receives fibres from the short head while its posterior portion receives fibres from the long head.

Nerve supply. It is supplied by a branch from the musculocutaneous nerve 5 and 6).

Actions. It is a powerful supinator of the forearm when the elbow is bent. It also flexes the elbow joint and, to a slight extent, the shoulder joint. It makes the antebrachial fascia tense through the bicipital aponeurosis. The long head of the biceps being passed through the shoulder joint and the intertubercular sulcus helps to retain the head of the humerus in the joint cavity. It acts like a lever in reducing a dislocated shoulder joint.

N.B.—Sometimes a third head exists, which arises from the shaft of the humerus from the upper and medial part of the brachialis muscle with which it is blended and is inserted into the bicipital aponeurosis and the medial part of its tendon.

Brachialis. It covers the lower half of the front of the humerus and forms the floor of the cubital fossa opposite the bend of the elbow joint.

Origin. It arises from the lower half of the antero-lateral and antero-medial surfaces of the shaft of the humerus and from the medial and lateral intermuscular septa. Superiorly it makes a v-shaped attachment and embraces the insertion of the deltoid from either side.

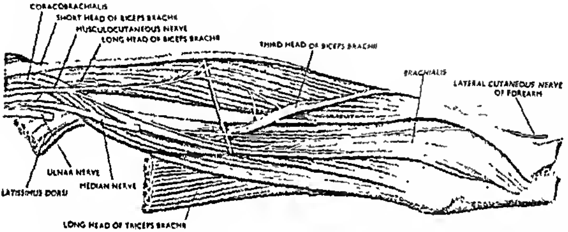


Fig. 520. The antero-medial aspect of left arm to show the third head of biceps brachii with its nerve supply. From the dissection hall, N. R. Sircar Medical College, Cal; with kind permission from the Prof. of Anatomy.

Insertion. Its fibres converge to a flat tendon which covers the front of the elbow joint where it is adherent to the capsular ligament and is inserted into the ulnar tuberosity of the coronoid process of the ulna.

Nerve supply. Its medial half is supplied by a branch from the musculocutaneous nerve (C. 5 and 6) while its lateral part is supplied by a branch from the radial nerve (C. 7). Radial N

The double nerve supply of the muscle is an indication about its composite character developmentally. In the foetal limb it consists of two portions, one occupies the flexor compartment and the other occupies the extensor compartment and consequently the two portions derive their nerve supply from two different sources (that which occupies the flexor compartment is supplied by the nerve of the same compartment and the other in the extensor compartment is supplied by the nerve of the same compartment).

Action. It flexes the elbow joint in approximating the forearm to the arm.

BACK OF THE ARM

The rounded muscular prominence on the back of the arm is caused by the three heads of the triceps brachii muscle which lies within the posterior osseo-fascial compartment formed by the posterior surface of the body of the humerus and the

lateral and the medial intermuscular septa and the deep fascia. The only superficial structures found in this region are the three cutaneous nerves, namely, the posterior cutaneous nerve of the arm, lower lateral cutaneous nerve of the arm and the posterior cutaneous nerve of the forearm.

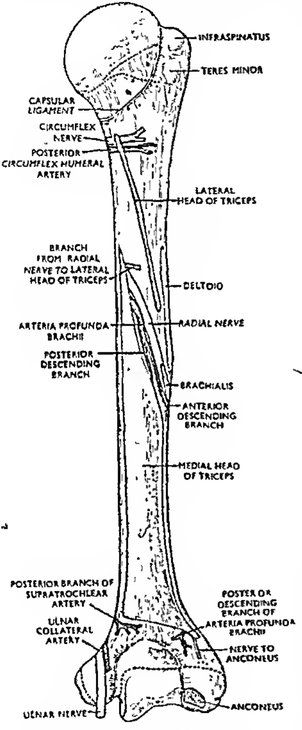


Fig. 521. The posterior view of the right humerus showing muscular and ligamentous attachments and some of its relations.

Triceps brachii. The triceps brachii is so named (*tri* = *three*, *ceps* = *heads*) because it has three heads of origin—long or scapular head, lateral and medial heads or humeral heads.

Origin. The long head or the scapular head arises by a tendon from the infraglenoid tubercle of the scapula blending with the capsular ligament of the humerus and forms a muscular belly which descends downwards between the teres major and teres minor and joins the posterior part of the medial head and the tendon of insertion.

The lateral head arises from a ridge on the posterior surface of the humerus and extends from below the teres minor to the spiral groove. It forms a muscular belly which joins the anterior part of the medial head and its tendon of insertion. In its course downwards it bridges across the spiral groove and covers the radial nerve and the profunda vessels.

The medial head arises from the posterior surface of the humerus below the spiral groove. It also arises from the back of the lateral and medial intermuscular septa.

Insertion. Its tendon of insertion begins as two aponeurotic lamellae which begin opposite the middle of the arm. The superficial lamella covers the back of the lower part of the medial head, the deep lamella being placed at the deeper plane in the substance of the medial head. The two lamellae unite to form a tendon above the elbow joint and is inserted into

posterior part of the top of the olecranon process of the ulna and *into the antebrachial fascia that covers the anconeus muscle.*

Nerve supply. It is supplied by the radial nerve by three branches (C. 6,7 and 8).

Actions. It is the extensor of the elbow joint. Its long head is a synergist to the adductors of the shoulder joint.

N.B.—During excision of the elbow joint the attachment of the triceps to the antebrachial fascia should always be preserved because even after excision of the elbow joint the triceps is still able to act on the forearm through this fascial connection. Division of this fascial connection will lead to loss of function of the triceps completely.

Subanconeus. It is the name given to a few fibres which spring from the deep surface of the lower part of the triceps and are inserted into the posterior part of the articular capsule of the elbow joint.

Subanconeus.

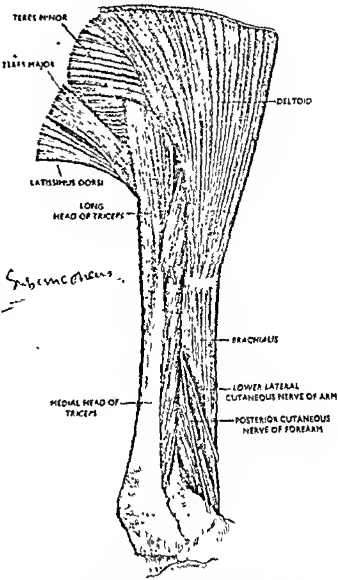


Fig. 522. The postero-lateral aspect of right arm to show the three heads of triceps, brachialis, brachio-radialis, extensor carpi radialis longus and some of the scapular muscles.
From the dissection hall, N. R. Sircar Medical College, Cal; with kind permission from the Prof. of Anatomy.

FRONT OF THE FOREARM

The front of the forearm begins from the line joining the two epicondyles of the humerus to the front of the wrist joint. The upper third of the front of the forearm is mainly occupied by the cubital fossa and has already been described.

The structures composing the front of the forearm are arranged in six layers and from before backwards they are the skin, superficial fascia, deep fascia, superficial layer of flexor muscles and the brachioradialis, deep layer of flexor muscles, and osseo-membranous layer (volar aspect of the ulna and radius and the interosseous membrane connecting the two bones). The cutaneous veins and the nerves lie in the superficial fascia. The deep vessels of the forearm are ulnar and radial arteries with their branches and the deep nerves are the ulnar and median nerves with their branches and the radial nerve.

Deep fascia of the forearm or the antebrachial fascia. The deep fascia of the forearm is strong and membranous and invests the muscles of the forearm. Its fibres are mainly transverse and partly oblique in direction. It is more thick

and strong posteriorly and is attached proximally to the epicondyles of the humerus and to the margins of the triangular surface on the back of the olecranon process. Posteriorly it receives expansions from the tendon of insertion of the triceps whereas anteriorly the expansions from the biceps form the bicipital aponeurosis. In the

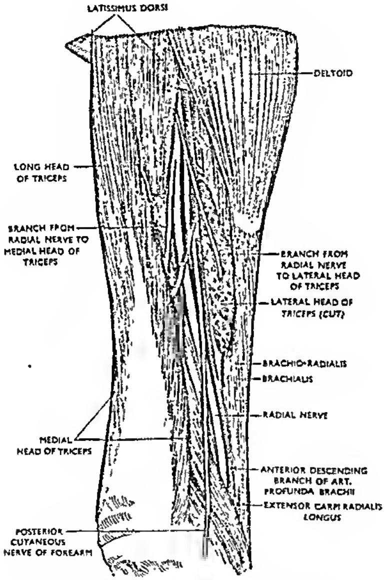


Fig. 523 The postero-lateral aspect of the right arm. A part of the lateral head of triceps has been removed to expose the radial nerve with its accompanying vessels. From the dissection hall, N. R. Sircar Medical College, Cal; with kind permission from the Prof. of Anatomy.

back of the forearm it is attached to the whole length of the posterior border of the ulna. Below and anteriorly it is continuous with the flexor retinaculum and below and posteriorly it is thickened to form the extensor retinaculum.

Superficial layer of the flexor muscles. The superficial layer of muscles consists of brachioradialis, pronator teres, flexor carpi radialis, palmaris longus, flexor digitorum superficialis (sublimis) and the flexor carpi ulnaris.

The brachioradialis forms the most lateral muscle on the upper part of the forearm where it forms a muscular belly and bounds the cubital fossa on the lateral side. Descending along the lateral side of the forearm it forms a tendon in the lower part of the forearm and passes to its point of insertion.

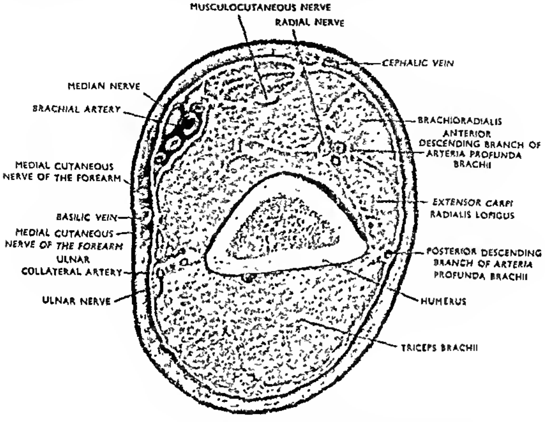


Fig. 524. A transverse section of the lower-third of the right arm. With kind permission from Lederle Laboratories—drawn by Mr. Paul Peck.

The pronator teres passes obliquely from medial to the lateral side to the middle of the shaft of the radius while the rest of the superficial flexors descend vertically downwards to their insertion and they are fleshy above and tendinous below. The superficial flexor muscles in the upper-third of the forearm, from lateral to the medial side, are the *pronator teres, flexor carpi radialis, palmaris longus, flexor digitorum superficialis (sublimis)* and the *flexor carpi ulnaris*. Above the wrist joint, from lateral to the medial side, they are flexor carpi radialis, palmaris longus, flexor digitorum superficialis (sublimis) and the flexor carpi ulnaris.

Functional Classification of the muscles of the front of the forearm—

(1) *Flexors of the elbow joint*—
  (a) Brachialis.
  (b) Biceps brachii.
  (c) Brachioradialis.

(2) *Supinators of the forearm*—
  (a) Supinator.
  (b) Biceps brachii.
  (c) Brachioradialis.

(3) *Pronators of the forearm*—
  (a) Pronator teres.
  (b) Pronator quadratus.
  (c) Brachioradialis.

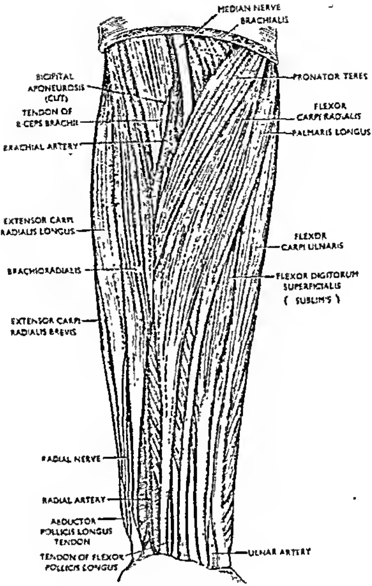


Fig. 525. The front of the left forearm.
From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

(4) *Flexors of the wrist joint* (Prime mover)—
(*a*) Flexor carpi radialis.
(*b*) Flexor carpi ulnaris.
(*c*) Palmaris longus.

Synergists—
(*a*) Flexor digitorum superficialis.
(*b*) Flexor digitorum profundus.
(*c*) Flexor pollicis longus.

(5) *Flexors of the digits*—
(*a*) Flexor digitorum superficialis.
(*b*) Flexor digitorum profundus.
(*c*) Flexor pollicis longus.

Flexor of the elbow joint—
(*a*) Biceps brachii—See front of the arm.
(*b*) Brachialis—See front of the arm.
(*c*) Brachioradialis.

Brachioradialis. It is the most superficial muscle on the lateral side of the forearm and forms a fleshy belly in the upper-half of the forearm while its lower half forms a flattened tendon.

Origin. It arises from the upper two-thirds of the lateral supracondylar line of the humerus and from the adjoining part of the anterior aspect of the lateral intermuscular septum. Its fleshy belly overlaps the radial artery and the radial nerve in the upper forearm, and in the lower arm, in the intermuscular furrow between it and the extensor carpi radialis longus on the lateral side and the brachialis on the medial side, there lies the anastomosis formed by the radial recurrent and the anterior descending branch of the arteria profunda brachii. In the lower forearm the radial artery lies on its medial side and radial nerve passes backwards by crossing the deep aspect of its tendon. Its lower end is crossed by the tendons of abductor pollicis longus et extensor pollicis brevis.

Insertion. It is inserted into the tubercle at the base of the styloid process of the radius at the junction of its lateral and anterior aspects.

Actions. It is a weak flexor of the elbow joint and acts best when the forearm is in midprone position. While the forearm is fully pronated it gets the leverage to supinate the forearm to the neutral position and similarly, while the forearm is fully supinated it aids pronation to the neutral position (W. H. Hollinshead).

Nerve supply. It is supplied by a branch from the radial nerve and receives its fibres from fifth and sixth cervical nerves.

The brachioradialis, though a flexor of the elbow joint, gets its inervation from the radial nerve which is a nerve of the extensor muscles.

Supinators of the forearm—
(*a*) *Biceps brachii.* See front of the arm.

(*b*) **Supinator.** It lies in the lateral part of the floor of the cubital fossa and covers the lateral, anterior and the posterior aspects of the upper-third of the radius.

Origin. It consists of superficial tendinous and deep muscular fibres and arises from the lateral epicondyle of the humerus, from the lateral ligament of the elbow joint, from the annular ligament and from the supinator crest of the ulna and the grooved area in front of it.

Insertion. It is inserted into the lateral aspect of the upper-third of the radius and reaches as low as the insertion of the pronator teres.

The posterior interosseous branch of the radial nerve passes between its superficial and deep set of fibres to the back of the forearm.

Nerve supply. It is supplied by the posterior interosseous branch of the radial nerve (C. 5 and 6) by two branches—one before the nerve passes through it and the other while it passes through the muscle.

Pronators of the forearm—
The pronator muscles by their action cause the forearm to turn backwards.

(*a*) **Pronator teres.** It consists of two heads, humeral and ulnar, which join together and passes obliquely from medial to the lateral side across the upper-third of the forearm.

Origin. The humeral head arises from the medial supracondylar ridge, from the medial epicondyle along with the common flexor tendon, from the intermuscular septum between it and the flexor carpi radialis and from the antebrachial fascia. The ulnar head, which is more deeply placed, arises from the medial margin of the coronoid process of the ulna below the origin of the flexor digitorum superficialis and joins the humeral head at an acute angle.

Insertion. The muscle crosses the upper part of the forearm obliquely and ends in a flat tendon which is inserted into a rough ridge on the middle of the lateral surface of the shaft of the radius.

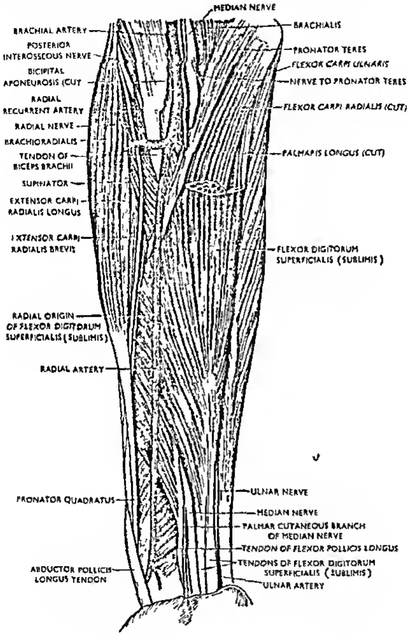


Fig. 526. The front of the right forearm with the removal of palmaris longus and flexor carpi radialis.
From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

The median nerve passes in between the two heads of the muscle and is separated from the ulnar artery by the deep or the ulnar head. The muscle in its course downwards and laterally froms the medial boundary of a traingular interval in front of the elbow joint, the cubital fossa.

Nerve supply. It is supplied by a branch from the median nerve (C. 6 and 7). The branch usually arises in front of the elbow joint but sometimes it may arise from the lower part of the arm.

(*b*) **Pronator quadratus.** It is a quadrilateral-shaped muscle situated deeply in front of the lower part of the forearm.

Origin. It arises from the oblique ridge on the lower part of the anterior surface of the body of the ulna, from the medial part of the anterior surface of the shaft of the ulna adjoining the oblique ridge and from the strong aponeurosis which covers the medial one-third of the muscle. The fibres consist of superficial and deep fibres.

Insertion. The superficial fibres pass downwards and laterally and are inserted into the anterior border and the anterior surface of the lower one-fourth of the radius.
The deep fibres are inserted in the triangular depression above the ulnar notch of the radius.

Nerve supply. It is supplied by the anterior interosseous branch of the median nerve (C. 6 and 7).

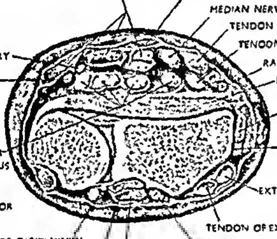


Fig. 527. A transverse section of the lower-fourth of the right forearm. With kind permission from Lederle Laboratories—drawn by Mr. Paul Peck.

Flexors of the wrist joint—

(*a*) **Flexor carpi radialis.** *Origin.* It lies on the medial side of the pronator teres and arises from the medial epicondyle of the humerus in common with the other flexor muscles and from the deep surface of the antebrachial fascia. It forms a fusiform muscular belly which soon ends in a tendon.

Insertion. It passes in between the superficial and the deep portions of the flexor retinaculum and lies in a groove of the trapezium and is inserted into the volar aspect of the base of the second and the third metacarpal bones.

Nerve supply. It is supplied by a branch from the median nerve (C. 6 and 7).

Actions. In addition to flexion it also abducts the wrist joint.

(*b*) **Palmaris longus.** *Origin.* It arises from the medial epicondyle of the humerus in common with the other flexor muscles and from the deep surface of

the antebrachial fascia. It forms a short fusiform muscular belly which soon ends in a tendon and lies on the medial side of the flexor carpi radialis.

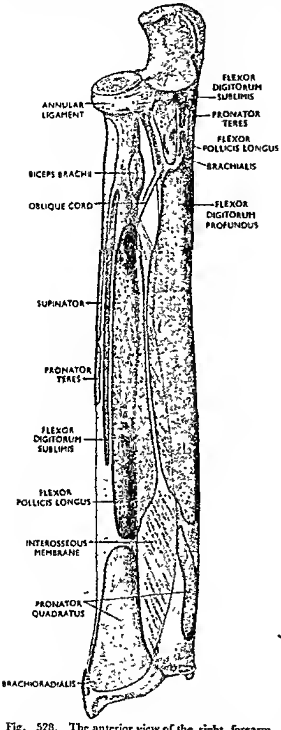


Fig. 528. The anterior view of the right forearm. Bones showing attachments.

Insertion. Its tendon crosses in front of the flexor retinaculum and is inserted into its distal part and into the apex of the central part of the palmar aponeurosis.

Nerve supply. It is supplied by a branch from the median nerve (C. 8).

(c) **Flexor carpi ulnaris.** *Origin.* It arises by two heads—humeral head and ulnar head and lies on the most medial part of the front of the forearm. The humeral head arises from the medial epicondyle of the humerus in common with the other flexor muscles. The ulnar head arises from the medial margin of the olecranon process of the ulna and from the upper two-thirds of the posterior border of the ulna by an aponeurosis in common with flexor digitorum profundus and extensor and flexor carpi ulnaris and from the intermuscular septum between it and the flexor digitorum superficialis.

Insertion. It forms a tendon which is inserted into the volar aspect of the pisiform bone and into the flexor retinaculum and by its tendinous expansion into the hamate (piso-hamate ligament) and into the fifth metacarpal bone (pisometacarpal ligament).

Nerve supply. It is supplied by a branch from the ulnar nerve (C. 8 and T. 1).

Actions. In addition to flexion of the wrist joint it is a powerful adductor of the wrist joint.

Flexors of the digits—

(a) **Flexor digitorum superficialis (sublimis).** It is the largest of all the superficial group of the flexor muscles in the forearm.

Origin. It arises by two heads—*humero-ulnar* and *radial.* The *humero-ulnar* head arises from the medial epicondyle of the humerus in a common tendon with other flexor muscles, from the anterior part of the medial ligament of the elbow joint, from the intermuscular septum between it and the other flexor muscles,

from the medial margin of the coronoid process of the ulna immediately above origin of the pronator teres. The *radial head* arises from the oblique line of the erior border of the shaft of the radius as far as the insertion of the pronator teres. two heads then unite together to form a muscular belly which soon divides into

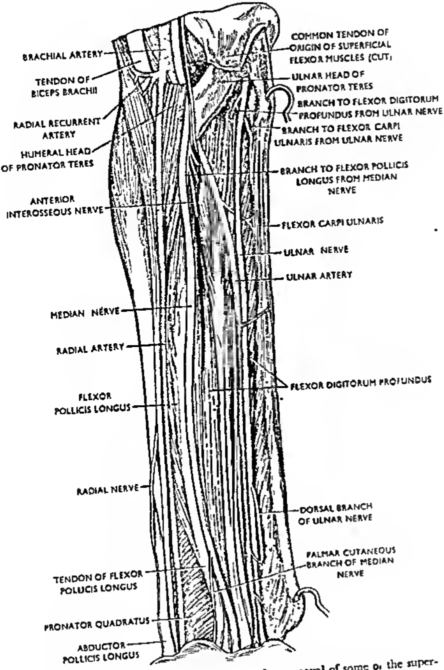


Fig. 529. The front of the right forearm after removal of some of the superficial flexor muscles.
From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

strata of muscle fibres—*superficial* and *deep*. The radial head of origin joins the superficial stratum and divides into two parts which end in tendons for middle and ring fingers. The deep stratum also divides into two parts which in tendons for the little and the index fingers. These four tendons pass beneath

the flexor retinaculum, being arranged in pairs, and as they pass through the palm of the hand they diverge from each other and the superficial ones pass towards the middle and ring fingers and deep ones pass to the little and index fingers.

Insertion. Opposite the base of the proximal phalanx of the medial four fingers each tendon splits into two slips to transmit the tendon of flexor digitorum profundus; the slips of the split tendon partially reunite behind the tendon of flexor digitorum profundus by decussating fibres to form a shallow bed for the profundus tendon and finally divides into two slips which are inserted into the sides of the middle phalanx.

Nerve supply. It is supplied by a branch from the median nerve (C. 7 and 8, and T. 1).

Actions. It is the flexor of the middle phalanges and in continued action, it also flexes the proximal phalanges and the wrist joint.

(*b*) **Flexor digitorum profundus.** It is a broad thick muscle which is situated on the ulnar side of the forearm deep to the superficial group of the flexor muscles.

Origin. It takes its origin by fleshy fibres from the upper three-fourths of the anterior and medial surfaces of the shaft of the ulna, from the medial surface of the olecranon process of the ulna, from the upper three-fourths of the posterior border of the ulna by an aponeurosis in common with the flexor and extensor carpi ulnaris and also from the medial half of the upper three-fourths of the anterior surface of the interosseous membrane.

Insertion. The muscle ends in four tendons which pass beneath the flexor retinaculum and the flexor digitorum superficialis; the tendon for the index finger separates from the rest in the forearm while the other three tendons separate out distally and diverge from each other. As they pass in the palm of the hand opposite the base of the proximal phalanges of the medial four fingers, each tendon passes through the gap in the tendon of the flexor digitorum superficialis. It is inserted into the base of the distal phalanx of the index, middle, ring and the little fingers.

In the palm of the hand four lumbrical muscles are associated with the tendons of the flexor digitorum profundus. The first two lumbricals are unipennate muscles and take their origin from the radial side of the tendon for the index and middle fingers. The third and the fourth lumbricals are bipennate muscles and take thier origin from the contiguous sides of the tendon for the third and fourth and the fourth and fifth fingers respectively.

Nerve supply. Its lateral half is supplied by the median nerve and its medial half by the ulnar nerve (C. 7, 8 and T. 1). The fleshy belly with its tendons and the lumbricals associated with the same tendons, have the same nerve supply.

Actions. Flexor digitorum profundus flexes the distal phalanges of the index, middle, ring and the little fingers. In continued action it flexes the middle and proximal phalanges and the wrist joint. It is antagonistic to the action of the lumbricals and the interossei muscles which are extensors of the distal phalanges. It is a strong gripping muscle and acts best when the wrist is extended.

Flexor retinaculum of the hand. It is a thickened band of fibres resembling an ordinary postagestamp which stretches across the front of the concavity formed by the articulated carpal bones. Thus an osseomembranous tunnel is formed through which flexor tendons of the digits and the median nerve enter into the hand. It is derived from the deep fascia of the forearm. As it is square-shaped it presents two surfaces and four borders.

Attachment. Medially its medial border is attached to the pisiform bone and the hook of the hamate bone. *Laterally* its lateral border splits up into two lamellae—*superficial* and *deep*. The superficial lamella is attached to the tubercle of the scaphoid bone and to the ridge on the trapezium while the deep lamella is attached to the medial lip of the groove on the trapezium.

The superficial and the deep lamellae by their attachment to the trapezium form a tunnel which is lined by a synovial sheath and transmits the flexor carpi radialis tendon. *Above*, its upper border is continuous with the antebrachial fascia and *below*, it gives origin to abductor pollicis brevis, opponens pollicis and the flexor pollicis brevis on the lateral side, and to abductor digiti minimi, opponens digiti

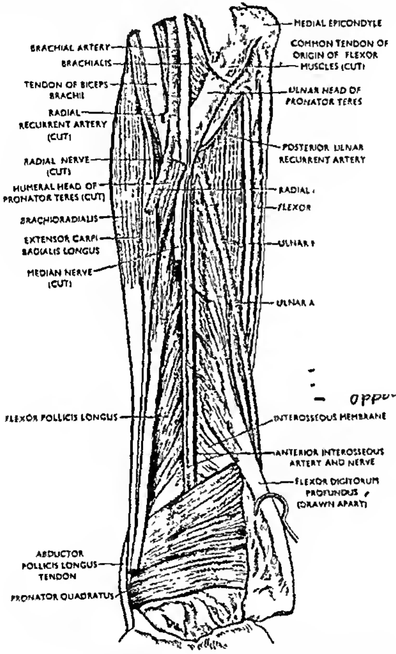


Fig. 530. The deep muscles on the front of the right forearm. Note the position of the anterior interosseous vessels and nerve.
From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Professor of Anatomy.

nimi and the flexor digiti minimi on the medial side. In between the attachments of the short muscles of the little finger and thumb it gives attachment to the apex of the central triangular portion of the palmar aponeurosis.

Relations. Superficially it is crossed by the ulnar nerve, ulnar artery, palmar cutaneous branch of the ulnar nerve, palmaris longus tendon and the palmar cuta-

neous branch of the median nerve in order from medial to the lateral side. The flexor carpi ulnaris muscle gains the insertion of some of its fibres on the medial side. A localised thickened portion of the antebrachial fascia covers the ulnar vessels and nerves on the medial side in front of the flexor retinaculum and is termed the *superficial part of the flexor retinaculum*. Deep to the flexor retinaculum the flexor pollicis longus muscle ensheathed by the synovial membrane occupies the lateralmost part of the carpal tunnel and occupying the rest of the carpal tunnel are the tendons of the flexor digitorum superficialis and flexor digitorum profundus muscles, the former passing in front of the latter. Lying in a recess formed by the tendons of the flexor digitorum sugerficialis et profundus on the medial side is the median nerve.

PALM OF THE HAND

General arrangements. The palm of the hand is the executive unit of the superior extremity and its unique function, the function of grasping or gripping an object, proves the existence of the superior extremity as a grasping organ. It forms a quadrilateral surface, from the distal end of which the digits or the fingers extend and they form the adjustable instruments for gripping. Of the five fingers the third or the middle one is the longest of all, the fourth or the ring finger, the index, the little and the thumb come next in order of their length. The skin-fold between the fingers is known as the web between the fingers, which froms the most dependent part of the palmar spaces.

On a general view the palm of the hand forms a central hollow with bilateral muscular eminences. The lateral muscular prominence, known as the *thenar eminence*, is caused by the underlying three short muscles of the thumb, namely, the abductor pollicis brevis, the flexor pollicis brevis and the opponens pollicis. The medial muscular prominence is known as the *hypothenar eminence* and is formed by the three short muscles of the little finger, namely, the abductor digiti minimi, the flexor digiti minimi and the opponens digiti minimi. The hollow of the palm is occupied by less muscles but more tendons, the flexor tendons for the digits (Flexor digitorum sublimis et profundus).

Fascial planes of the hand. If a transverse section is made across the palm six layers of fascia from before backwards can be seen, namely, the superficial fascia of the palm, the deep fascia of the palm, the anterior interosseous fascia, the posterior interosseous fascia, the deep fascia of the dorsum of the hand and the superficial fascia of the dorsum of the hand. The superficial fascia of the palm is blended with the skin and cannot be seen as a separate entity. The superficial fascia on the dorsum is also difficult to be reflected separately owing to its extreme thinness.

Palmar aponeurosis. The palmar aponeurosis is the deep fascia of the palm of the hand and consists of a thin lateral and a medial portion which covers the muscles of the thenar and hypothenar eminences, and a thick central portion, which covers the superficial palmar arch, median and the ulnar nerves, flexor tendons (flexor digitorum sublimis et profundus) and the lumbrical muscles. Its central portion is triangular in shape, the apex of which is attached to the flexor retinaculum and is continuous with the palmaris longus tendon. Its base is directed downwards and opposite the middle of the palm it divides into four slips or digital processes which diverge from one another and pass to the medial four fingers, one for each finger. From either margin of the digital process a deep process passes backwards to be fused with the fibrous sheath of the flexor tendons. Opposite the heads of the metacarpal bones it forms a transverse thickened band known as the *superficial transverse palmar ligament*. Opposite the free end of the skin of the web between the fingers a series of transverse fibres arise from the digital processes which form a support for the skin of the web and is known as the *interdigital ligament*. From the interdigital ligament fibres are continued along the contiguous sides of the finger which are blended with the skin and are known as the *cutaneous ligament of the digit or Clelands ligament*. On either side, the central portion of the palmar

aponeurosis is continuous with the peripheral portions i.e. the fascia covering the thenar muscles laterally and the hypothenar muscles medially.

Three processes—the medial, lateral and intermediate palmar septa, pass backwards from the deep surface of the palmar aponeurosis. The *medial palmar septum* passes backwards from the medial margin of the central triangular portion of the palmar aponeurosis and fuses with the fascia covering the muscle in front of

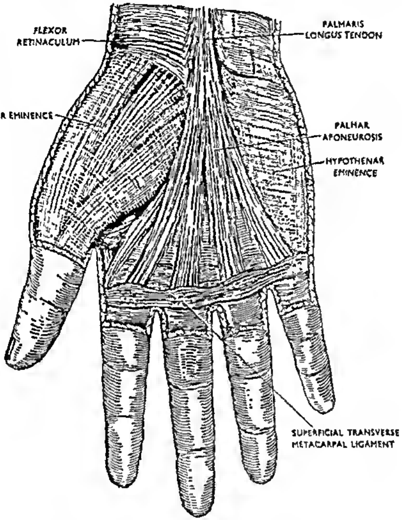


Fig. 531. The front of the palm of the right hand to show the palmar aponeurosis. From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Professor of Anatomy.

the fifth metacarpal bone. The *lateral palmar septum* passes backwards from the lateral margin of the central portion and fuses with the fascia covering the muscle in front of the first metacarpal bone. The mid-palmar or *intermediate palmar septum* passes obliquely backward from behind the flexor tendons of the index finger (Kanavel) and is attached to the front of the third metacarpal bone.

Anterior interosseous fascia. It is the thin fascia that covers the front of the interossei muscles. Inferiorly opposite the heads of the medial four metacarpal bones, this is thickened to form the *deep transverse ligament of the palm.* Laterally it covers the adductor pollicis muscle and reaches the first metacarpal bone where it is attached along its lateral margin and then is continuous with the posterior interosseous fascia.

Posterior interosseous fascia. It lies deep to the extensor tendons and covers the posterior aspects of the metacarpal bones and the interossei muscles.

These different fasciae together with the deep septa enclose different spaces in the hand known as the fascial compartments of the hand. The following are the different fascial compartments in the hand.

Thenar Space. It is the space between the intermediate and the lateral palmar septa.

Boundary. *Anteriorly* it is bounded by the central portion of the palmar aponeurosis. *Posteriorly*, it is bounded by the fascia in front of the transverse head of the adductor pollicis extending from the third metacarpal to the first metacarpal bone. *Laterally* it is bounded by the lateral palmar septum and *medially* by the intermediate palmar septum. Superiorly it communicates with the Parona's space by a narrow tubular space. Inferiorly it communicates with the subcutaneous space at the web between the thumb and the index fingers through the first lumbrical canal.

Contents. (1) Flexor pollicis longus tendon together with its synovial sheath. (2) Digital vessels and nerves for the thumb and the radial side of the index finger. (3) First lumbrical muscle.

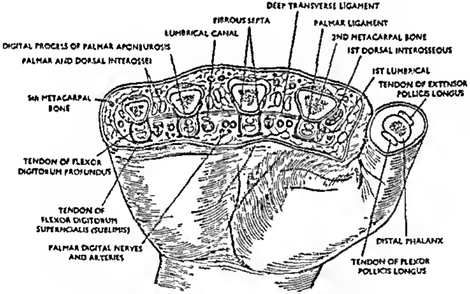


Fig. 532. A transverse section through the right hand.

Mid-palmar space. It is the space enclosed between the intermediate and the medial palmar septa.

Boundary. *Anteriorly* it is bounded by the central portion of the palmar aponeurosis. *Posteriorly* it is bounded by the anterior interosseous fascia extending from the third to the fifth metacarpal bone. *Laterally* it is limited by the intermediate palmar septum and *medially* by the medial palmar septum. Superiorly it communicates with the Parona's space and inferiorly it communicates with the subcutaneous space at the webs between the third and the fourth and the fourth and the fifth fingers by narrow tubular spaces known as the *lumbrical canals* through which the lumbrical muscles pass to the back of the digit.

Contents (1) Flexor tendons for the third and fourth fingers and also the flexor tendon for the fifth finger together with its synovial sheath. (2) Second, third and

the fourth lumbrical muscles. (3) Superficial palmar arch. (4) Digital vessels for the little, ring and the medial side of the middle fingers.

Hypothenar space. It is a small space contained in front of the fifth metacarpal bone.

Distal pulp space. It is a closed compartment situated in front of the distal phalanx. This space is separated from the insertion of the flexor pollicis longus in the thumb and from the flexor digitorum profundus in other fingers by a septum derived from the deep fascia that stretches from the skin to the phalanx and lies at a distance of one-third an inch from the distal digital crease.

The closed space is bounded in front and at the sides by the skin and behind by the distal phalanx. This space is divided into several compartments by longitudinal fibrous septa extending between the skin and the periosteum covering the distal phalanx. The proximal one-third of the distal phalanx lies outside the pulp space and corresponds to the epiphyseal end of the bone which gets its artery supply by a branch which arises from the digital artery opposite the middle segment of the digit. The remaining portion of the distal phalanx lies within the pulp space and gets its artery supply from the arteries supplying the pulp. The lymphatics of the pulp space freely communicate with the lymphatics of the periosteum of the distal phalanx in this space.

N.B.—Infection of the pulp space is too frequent and due to the above anatomical facts the infection easily spreads into the distal 2/3 of the terminal phalanx and causes its necrosis. Even if there is necrosis complete regeneration is possible because its proximal epiphyseal portion remains undamaged.

Dorsal subcutaneous space. It is an extensive area of areolar tissue on the back of the hand that intervenes between the extensor digitorum tendons and the skin and superficial fascia. Its outline is indefinite.

Dorsal subaponeurotic space. It is the space between the extensor digitorum tendons and the posterior interosseous fascia.

Parona's space. It is the space between the superficial and the deep group of flexor muscles in the forearm. It communicates below with the palmar spaces beneath the flexor retinaculum.

Synovial sheath of the flexor tendons of the palm. The flexor tendons reaching the palm of the hand are those of the flexor digitorum superficialis et profundus and the flexor pollicis longus. As these tendons enter the palm of the hand they are enveloped by synovial sheath; there are two synovial sheaths—one common sheath enveloping the tendons of the flexor digitorum superficialis (sublimis) and the flexor digitorum profundus and the other is a separate sheath for the tendon of the flexor pollicis longus. Each sheath extends into the forearm for a distance of about 2·5 cm. above the flexor retinaculum. Below the flexor retinaculum, the common sheath for the flexor digitorum superficialis et profundus extends into the palm as far as the middle of the metacarpal bones, where around the tendons for the index, middle and ring fingers it ends in blind diverticula but in case of the tendon for the little finger it is continuous with the digital synovial sheath of the tendon and extends as far as the distal interphalangeal joint. The sheath for the flexor pollicis longus is also continuous with the digital sheath of the thumb finger and extends up to the distal interphalangeal joint of the thumb. This sheath may all-through remain separated from the common sheath or it may communicate with the same behind the flexor retinaculum.

The common sheath consists of a parietal layer and a visceral layer covering the flexor tendons. The parietal layer first lines the carpal tunnel, then the inner surface of the flexor retinaculum and finally is reflected on to the front of the tendons of the flexor digitorum superficialis from the lateral side. Then it reaches the medial side of the same tendons, covers them from behind, and then is reflected on to the tendons of the flexor digitorm profundus and covers them from in front and lastly covers their posterior aspect. Thus it is evident that the tendons are invaginated

by the sheath and a recess is formed between the two groups of tendons on the medial side.

N.B.—From the nature of distribution of the sheaths it is evident that in case of any infection of the digits, the infections of the little and thumb fingers are to be cared much because there is every possibility of the infection being carried to the common sheath.

Fibrous sheath of the flexor tendons. The flexor tendons, as they enter the digit, are housed in an osseo-aponeurotic canal formed posteriorly by the phalanges and the palmar ligaments of the interphalangeal joints and in front by an arched band of fibres which covers them in front and are attached to the margins of the phalanges and the palmar ligaments of the interphalangeal joints. Opposite the middle and proximal phalanges the fibrous sheath is very strong and membranous and consists mainly of transverse fibres and is known as the vaginal ligaments. Opposite the interphalangeal joints it is composed of both annular and cruciate fibres.

The fibrous sheath is lined internally by synovial membrane, which after lining the walls of the fibrous sheath is reflected on to the tendons contained within it. As the flexor tendons approach their insertion they are connected to the posterior wall of the osseo-aponeurotic canal by cord-like synovial processes known as the *vincula tendinum.* The vincula tendinum, acts as a mesotendon and conveys minute blood vessels to the tendons for their nutrition although they get their main nutrition from the synovial fluid. The vincula tendinum is of two types—*vincula brevia* and *vincula longa.*

The *vincula brevia* are two in number and are short triangular processes of synovial membrane which connect the flexor tendons to the posterior wall of the osseo-aponeurotic canal just before their insertion. Thus it connects the flexor digitorum superficialis tendon to the front of the proximal interphalangeal joint and the flexor digitorum profundus to the front of the distal interphalangeal joint.

The *vincula longa* are thread-like processes of which two are found in association with the flexor digitorum superficialis tendon and one with the flexor digitorum profundus tendon. The vincula longa for the flexor digitorum superficialis are attached to it one on each side when it splits to give exit to flexor digitorum profundus tendon. Posteriorly they are attached to the posterior wall opposite the margins of the proximal end of the proximal phalanx. The vincula longa for the profundus tendon is attached to it immediately after it has pierced the flexor digitorum superficialis tendon.

Lumbrical muscles of the hand. The lumbricals are four in number and each consists of a small fasciculus of muscle fibres which arises from the tendon of the flexor digitorum profundus muscle. The first and second arise from the radial side and palmar surfaces of the tendons of the index and middle fingers respectively; the third and the forurth are bipennate muscles and arise by two heads—the third arising from the contiguous sides of the tendons of the middle and ring fingers and the fourth arising from the contiguous sides of the tendons of the ring and little fingers. Each muscle ends in a tendon which passes laterally and is inserted partly to the lateral side of the base of the proximal phalanx and mainly to the extensor expansion of the extensor digitorum tendon.

Nerve supply. They are supplied by branches from the median and ulnar nerves (C. 6, 7, 8 and T. 1). The first and the second are supplied by the median nerve and the third and the fourth are supplied by the deep terminal branch of the ulnar nerve. The third sometimes may be supplied by the median nerve and in that case it is not supplied by the deep branch of the ulnar nerve.

Actions. Each lumbrical muscle acting singly flexes the proximal phalanx and acting together with the palmar and dorsal interossei extends the middle and the distal phalanges of the medial four fingers. The extension of the proximal phalanx is caused by the extensor digitorum; the lumbrical muscle, though a very small muscle, acts as an antagonist to the extensor digitorum which is a powerful muscle. Extension of the middle and the distal phalanges by it is antagonised by the flexor

digitorum superficialis et profundus and this is best manifested during writing when flexion of the proximal phalanx and the extension of the middle and the distal phalanges take place alternately by the downstroke and the upstroke of the pen respectively.

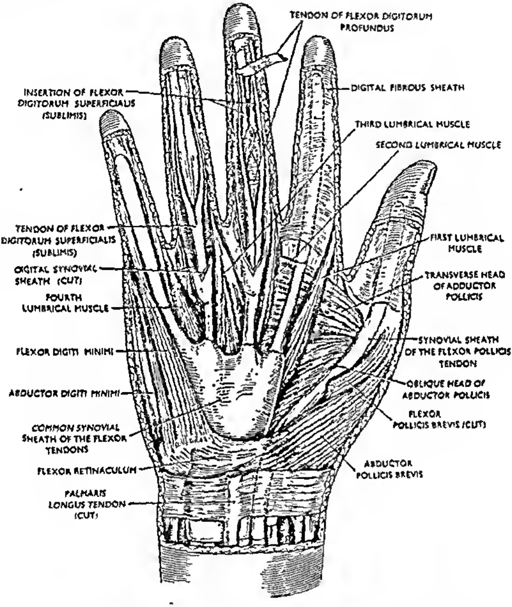


Fig. 533. The palm of the hand, right side, to show the *flexor tendons, their synovial sheaths and the associated structures.*

Interossei muscles of the hand. The interossei muscles of the hand occupy the interval between the metacarpal bones and are grouped into a dorsal and a palmar set.

Dorsal interossei muscles. They are four in number and are named by number according as the inter-metacarpal space they occupy. They are bipennate muscles and each arises by two heads, radial and ulnar, from the contiguous sides of the metacarpal bones. Each ends in a short tendon which winds backwards round the proximal phalanx and is inserted partly into the proximal phalanx and partly into the extensor expansions of the extensor digitorum muscle. The first

dorsal interosseous muscle is inserted into the radial side of the proximal phalanx of the index finger, the second into the radial side of the proximal phalanx of the middle finger, the third to the medial or ulnar side of the same finger; and the fourth dorsal interosseous is inserted into the ulnar side of the base of the proximal phalanx of the ring finger.

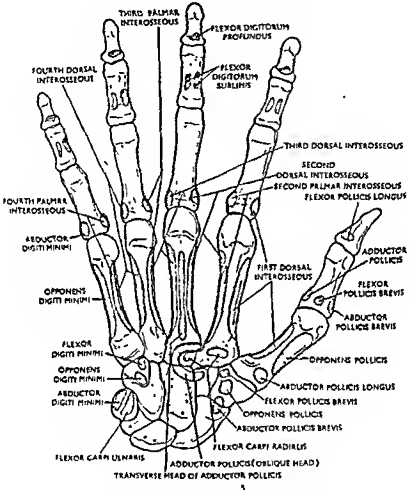


Fig. 534 The anterior view of the skeleton of the right hand showing the muscular attachments.

Palmar interossei muscles. They are four in number and occupy the anterior aspect of the intermetacarpal spaces. With the exception of the first, each arises from the entire length of the shaft of the metacarpal bone and is inserted into the proximal phalanx and to the extensor expansion on the back of the same digit.

The first palmar interosseous muscle arises from the medial aspect of the base of the first metacarpal bone and is inserted into the ulnar side of the base of the proximal phalanx of the thumb in common with the oblique head of the adductor pollicis muscle. The second arises from the ulnar side of the shaft of the second metacarpal bone and is inserted into the ulnar side of the proximal phalanx of the index finger. The third arises from the radial side of the shaft of the fourth metacarpal bone and is inserted into the same side of the proximal phalanx of the ring finger. The fourth arises from the radial side of the fifth metacarpal bone and is inserted into the same side of the proximal phalanx of the little finger.

Nerve Supply. All the interossei muscles (both palmar and dorsal) are supplied by the deep branch of the ulnar nerve (C. 8 and T. 1).

Actions. The dorsal interossei muscles abduct the fingers from an imaginary plane passing through the middle finger. The palmar interossei muscles adduct the fingers to that plane. Both the palmar and dorsal interossei acting with lumbricals flex the proximal phalanx and extend the middle and the distal phalanges. The first palmar interosseous muscle flexes the proximal phalanx of the thumb.

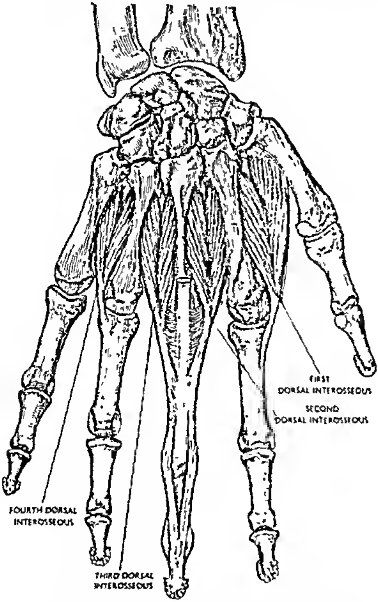


Fig. 535. *The skeleton of the right hand, dorsal aspects, to show the dorsal interossei and their insertions.*

Superficial group of extensor muscles. Except the anconeus which occupies the interval between the olecranon and the lateral condyle of the humerus, from lateral to medial side, the superficial extensors, are as follows:-

(1) Brachioradialis.
(2) Extensor carpi radialis longus.
(3) Extensor carpi radialis brevis.
(4) Extensor digitorum.

(5) Extensor digiti minimi.
(6) Extensor carpi ulnaris.

The deep group of extensor muscles on the back of the forearm except the supinator which lies obliquely across the upper-third of the back of the forearm, from lateral to medial side, are as follows:

(a) Abductor pollicis longus.
(b) Extensor pollicis brevis.
(c) Extensor pollicis longus.
(d) Extensor indicis.

Aneonens. It arises from the postero-inferior part of the lateral condyle of

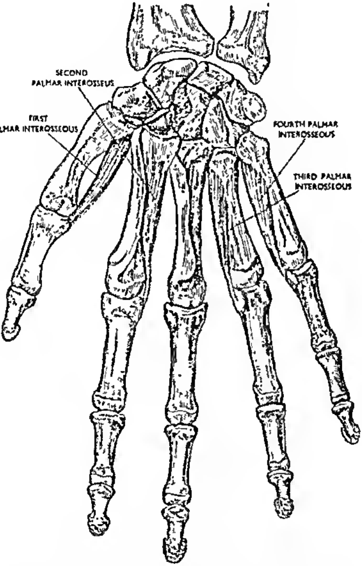


Fig 536 The skeleton of the right hand to show the attachments of the palmar interossei.

the humerus and is inserted into the lateral surface of the olecranon process and into the posterior surface of the shaft of the ulna above the oblique line.

Nerve Supply. It is supplied by a branch of the radial nerve which supplies the

medial head of the triceps and contains fibres from the seventh and eighth cervical nerves.

Actions. It assists the triceps in extending the elbow.

N.B.—The tendon of insertion of the triceps gives an aponeurotic expansion which covers the anconeus and then is continuous with the deep fascia of the forearm. In excision of the elbow when the triceps is separated from the olecranon subperiosteally this aponeurotic connection with the anconeus must be preserved because this aponeurotic connection, even after excision of the elbow, will enable the triceps to extend the elbow.

DORSUM OF THE HAND

The majority of the muscles of the back of the forearm except the supinator and brachioradialis reach the back of the hand as tendons and are inserted into their respective destinations. Except the first dorsal interosseous no fleshy belly of any

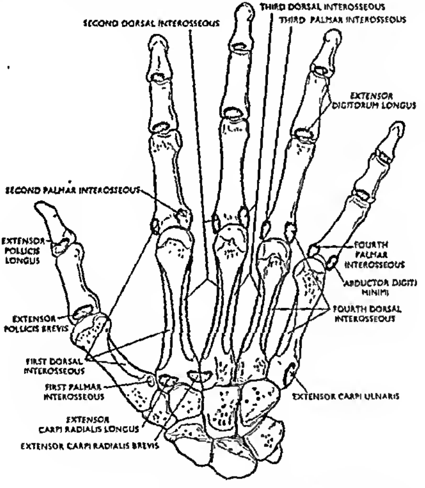


Fig. 537. The skeleton of the right hand, dorsal aspect, to show the muscular attachments.

muscle can be found in this region after exposure of the skin and fascia. The tendons of the muscles as they pass along the back of the wrist joint are bound down to the back of the radius and ulna by localised condensation of the deep fascia known as the *extensor retinaculum.* Vertical septa pass forwards from the deep surface of the extensor retinaculum and subdivide the space into different compartments, each of which is lined by synovial membrane for the tendons it transmits. Superficial to the tendons and opposite the middle of the metacarpal bone is the dorsal

venous network formed by the union of the three dorsal metacarpal veins, one from each of the second, third and fourth intermetacarpal spaces, and the dorsal digital veins from both sides of the thumb, radial side of the index and the medial side of the little finger. From the lateral side of the dorsal venous network the cephalic vein arises while from its medial side the basilic vein arises. Five digital branches of the radial nerve—two for the thumb, one for the radial side of the index, one for contiguous sides of index and middle and one for the contiguous sides of the middle and ring fingers—will be found on the dorsum of the hand before reaching their destination. The most medial digital branch from the radial nerve gives a communicating twig to the dorsal branch of the ulnar nerve. It lies on the medial side of

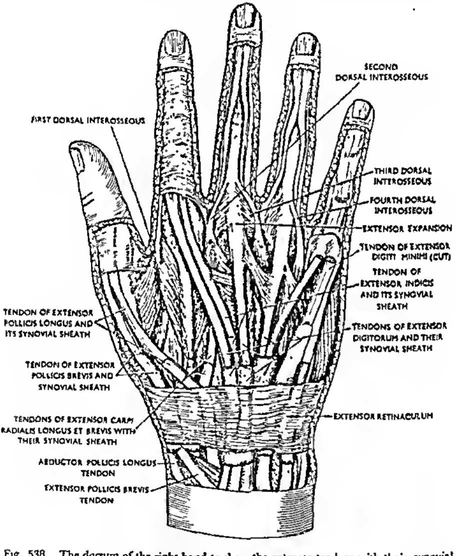


Fig. 538 The dorsum of the right hand to show the extensor tendons with their synovial sheaths and the associated structures.

the dorsum of the hand and divides into two branches—one supplies the medial side of the little finger while the other communicates with the radial nerve. It then divides into two branches which supply the contiguous sides of the little and the ring fingers. The digital branches of the radial nerve that reach the thumb, cross the anatomical snuffbox and cross in this situation the origin of the cephalic vein,

and the radial artery which lies in the floor of the *anatomical snuff-box*. The anatomical snuff-box is bounded in front by extensor pollicis brevis and behind by the extensor pollicis longus tendon. Its floor is formed by the lateral ligament of the wrist joint and it is roofed by the skin and superficial fascia.

The tendons of abductor pollicis longus, extensor pollicis brevis et longus pass obliquely to the thumb and cross superficial to the tendons of extensor carpi radialis longus et brevis which descend *vertically* downwards to their destination. The arrangements of the tendons on the back of the hand from lateral to medial side are as follows :

(1) Abductor pollicis longus.
(2) Extensor pollicis brevis.
(3) Extensor carpi radialis longus.
(4) Extensor carpi radialis brevis.
(5) Extensor pollicis longus.
(6) Extensor digitorum.
(7) Extensor indicis.
(8) Extensor digiti minimi.
(9) Extensor carpi ulnaris.

The extensor digitorum consists of four tendons, one for each of the index, middle, ring and the little fingers. The extensor indicis tendon lies partly under cover of and partly on the medial side of the tendon of the extensor digitorum for the index finger and similarly the tendon of the extensor digiti minimi also lies on the medial side of the extensor digitorum tendon for the little finger.

Functional classification of the muscles on the back of the forearm—

The muscles on the back of the forearm may be classified as follows:

(1) *Extensors of the wrist joint* (Transverse axis) :
- (a) Extensor carpi radialis longus.
- (b) Extensor carpi radialis brevis.
- (c) Extensor carpi ulnaris.

(2) *Extensors of the thumb* :
- (a) Extensor pollicis longus.
- (b) Extensor pollicis brevis.
- (c) Abductor pollicis brevis.
- (d) Flexor pollicis brevis.

(3) *Extensors of the proximal phalanges of the medial four digits* :
- (a) Extensor digitorum.
- (b) Extensor indicis—Extends only the proximal phalanx of the index finger.
- (c) Extensor digiti minimi—Extends only the proximal phalanx of the little finger.

(4) *Abductors of the thumb* :
- (a) Abductor pollicis longus.
- (b) Extensor pollicis brevis.
- (c) Abductor pollicis brevis.
- (d) Opponens pollicis.
- (e) Abductor pollicis (In case of extreme position of opposition only) (Morris).

Extensors of the wrist joint—

(a) **Extensor carpi radialis longus.** *Origin.* It arises from the lower one-third of the lateral supracondylar ridge of the humerus, from the lateral intermuscular septum and from the lateral epicondyle of the humerus in common with the other extensor muscles.

Insertion. It ends in a tendon opposite the middle-third of the forearm and descends vertically downwards deep to the abductor pollicis longus et extensor

pollicis brevis and is inserted into the dorsal aspect of the base of the second metacarpal bone.

Nerve supply. It is supplied by a branch from the radial nerve (C. 6 and 7).

Action. In addition to extension it abducts the wrist joint together with the flexor carpi radialis.

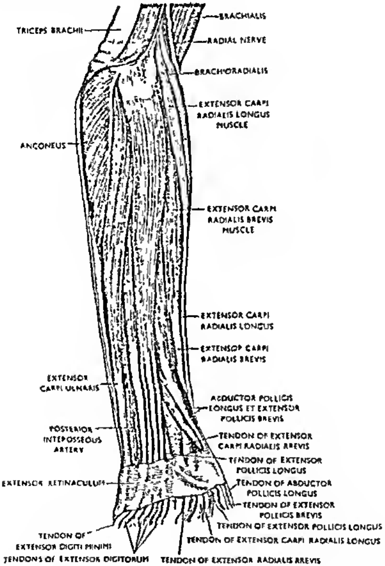


Fig. 539. The dorsum of the right forearm to show the superficial extensor muscles. From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

(*b*) **Extensor carpi radialis brevis.** *Origin.* It arises from the lateral epicondyle of the humerus in common with the other extensor muscles, from the lateral ligament of the elbow joint and from the intermuscular septum between it and the adjacent muscles.

Insertion. It forms a flat tendon which lies on the medial side of the extensor carpi radialis longus and is inserted into the dorsal aspect of the base of the third metacarpal bone.

Nerve supply. It is supplied by a branch from the posterior interosseous nerve (C. 6 and 7).

Actions. Same as above.

(*c*) **Extensor carpi ulnaris.** *Origin.* It arises from the lateral epicondyle of the humerus in common with the other extensor muscles, from the posterior border of the ulna by an aponeurosis in common with flexor carpi ulnaris and the flexor digitorum profundus and from the antebrachial fascia.

Insertion. It is inserted by a tendon in the tubercle on the medial side of the base of the fifth metacarpal bone.

Nerve supply. It is supplied by a branch from the posterior interosseous nerve (C. 6, 7 and 8).

Actions. In addition to extension of the wrist joint it is a powerful adductor of the same joint.

Abductor pollicis longus. *Origin.* It arises from the posterior surface of the radius above the extensor pollicis brevis, from the back of the interosseous membrane and from the upper part of the lateral area on the posterior surface of the ulna.

Insertion. It forms a tendon which is inserted into the lateral aspect of the base of the first metacarpal bone.

Nerve supply. It is supplied by a branch from the posterior interosseous nerve (C. 6, 7 and 8).

Actions. In addition to abduction it also extends the thumb at the carpo-metacarpal joint by acting with the extensors of the thumb.

Extensor digitorum. *Origin.* It arises from the lateral epicondyle of the humerus by common extensor tendon, from the intermuscular septum between it and the other extensor muscles and from the antebrachial fascia. After its origin the muscular belly descends downwards and soon divides into four tendons which with the extensor indicis tendon pass through a separate compartment of the extensor retinaculum and then diverge from each other and pass towards the index, middle, ring and the little fingers. Each tendon opposite the metacarpo-phalangeal joint is expanded (extensor expansion) by the union with the insertions of lumbricals and interossei muscles and covers the back of this joint. Immediately above the metacarpo-phalangeal joint the tendons are connected to one another by the oblique aponeurotic fibres.

Insertion. Each tendon divides into three slips—two collateral and one intermediate. The intermediate slip is inserted into the back of the middle phalanx while the two collateral slips further run downwards and soon reunite together to be inserted into the back of the distal phalanx.

Nerve supply. It is supplied by the posterior interosseous nerve (C. 6, 7 and 8).

Action. It causes extension of the proximal phalanges of the medial four fingers and thus is antagonistic to the action of lumbrical muscles which are the flexors of the proximal phalanges. In continued action it causes extension of the wrist joint. Due to aponeurotic connections between its tendons, during flexion of the digits, the tendons move medially over the back of the metacarpal bones and flexion of individual digit is impossible without causing some flexion of the other digits.

Muscles attached to the phalanges of the thumb. The following are the muscles attached to the phalanges of the thumb.

(1) Abductor pollicis brevis.
(2) Flexor pollicis brevis.
(3) Adductor pollicis.
(4) First palmar interosseous.
(5) Flexor pollicis longus.

(6) Extensor pollicis longus.
(7) Extensor pollicis brevis.

(1) **Abductor pollicis brevis.** *Origin.* It arises from the flexor retinaculum, tubercle of the scaphoid, crest of the trapezium and also from the tendon of the abductor pollicis longus.

Insertion It forms a short tendon which blends with the tendon of the flexor pollicis brevis and this common tendon is inserted into the tubercle on the lateral margin of the base of the proximal phalanx of the thumb and to the lateral margin of the extensor pollicis longus.

Nerve supply. It is supplied by a branch from the median nerve (C. 6 and 7).

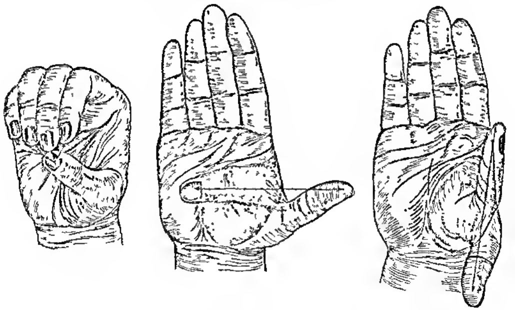
Actions It *flexes* the metacarpo-phalangeal joint of the thumb. It *abducts* the thumb, i.e. it carries the thumb forwards and medially and the movement takes place in the carpometacarpal joint. By having its attachment to the extensor pollicis longus it acts as a *weak extensor* of the distal phalanx when the extensor pollicis longus is paralysed.

(2) **Flexor pollicis brevis.** *Origin.* It arises from the lower part of the flexor retinaculum and from the lower part of the crest of the trapezium.

Insertion It forms a short tendon which joins with the abductor pollicis brevis tendon and is inserted into the radial side of the base of the proximal phalanx of the thumb.

Nerve supply. It is supplied by a branch from the median nerve (C. 6 and 7).

Actions. It is the flexor of the metacarpo-phalangeal joint of the thumb and it acts in a similar manner like the abductor pollicis brevis.



A B C

Fig. 540. A. Shows the movement of opposition.
B. Shows flexion and extension.
C. Shows abduction and adduction.

(3) **Adductor pollicis.** *Origin.* It consists of *oblique* and *transverse heads*. The *oblique head* arises from the capitate and trapezoid bones, from the palmar aspects of the bases of the second and the third metacarpal bones, from the palmar ligament of the carpal bones and also from the sheath of the flexor carpi radialis tendon.

The *transverse head* arises from the ridge on the anterior aspect of the third metacarpal bone.

Insertion. The two heads unite to form a short tendon which joins with the first palmar interosseous and is inserted to the ulnar side of the base of the proximal phalanx of the thumb and by a few slips to the flexor pollicis longus tendon. In its course, the adductor pollicis gains its attachment to ulnar and radial sesamoid bone of the metacarpo-phalangeal joint.

Nerve supply. It is supplied by the deep branch of the ulnar nerve (C. 8 and T. 1).

Actions. The transverse head causes flexion and adduction of the thumb while the oblique head, by virtue of its attachment to the radial sesamoid bone of the metacarpo-phalangeal joint, is competent to cause the movement of opposition when the median nerve is paralysed. The movement of opposition, as in pinching, is usually carried out by the opponens pollicis. It is also a weak flexor of the distal phalanx of the thumb.

(4) **First palmar interosseous.** It arises from the medial aspect of the base of the first metacarpal bone and after joining the adductor pollicis tendon it is inserted on the medial aspect of the base of the proximal phalanx of the thumb.

Action. It is the flexor of the metacarpo-phalangeal joint and adductor of the thumb.

(5) **Flexor pollicis longus.** *Origin.* It arises from the upper three-fourths of the anterior surface of the shaft of the radius, from the anterolateral part of the interosseous membrane and from the medial margin of the coronoid process of the ulna below the pronator teres.

Insertion. It forms a tendon which crosses the flexor carpi radialis tendon at the wrist and then intervenes between the flexor pollicis brevis on the radial side and the first palmar interosseous and the adductor pollicis on the ulnar side and is finally inserted into the volar aspect of the base of the distal phalanx of the thumb. Its tendon is covered by a synovial sheath.

Nerve supply. It is supplied by the anterior interosseous branch of the median nerve (C. 7, 8 and T. 1).

Actions. It is the flexor of the distal phalanx of the thumb and in continued action it flexes the metacarpo-phalangeal and the wrist joints.

(6) **Extensor pollicis longus.** *Origin.* It arises from the lateral part of the posterior surface of the shaft of the ulna below the abductor pollicis longus and from the back of the interosseous membrane.

Insertion. It forms a tendon which passes through a separate compartment on the medial side of the dorsal tubercle of the radius and crosses the radial artery in the anatomical snuff-box and is finally inserted to the dorsal aspect of the base of the distal phalanx of the thumb.

Nerve supply. It is supplied by the posterior interosseous branch of the radial nerve (C. 7 and 8).

Actions. It is the extensor of the distal phalanx of the thumb and in continued action acts as an extensor of the metacarpo-phalangeal and the carpometacarpal joints of the thumb. It also rotates the thumb at the carpometacarpal joint laterally so that the pulp of the thumb faces forwards like the other digits and this can be explained by the fact that it reaches the thumb from the ulnar side of the forearm. Normally the thumb is rotated medially by the opponens pollicis. Thus extensor pollicis longus is a true antagonist to the opponens pollicis. In case of paralysis of the intrinsic muscles of the hand it rotates the thumb laterally giving rise to *ape hand deformity.*

(7) **Extensor pollicis brevis.** *Origin.* It arises from the posterior aspect of the shaft of the radius below the abductor pollicis longus and from the adjoining portion of the interosseous membrane.

Insertion. It ends in a tendon which accompanies the abductor pollicis longus tendon and is inserted into the dorsal aspect of the base of the proximal phalanx of the thumb.

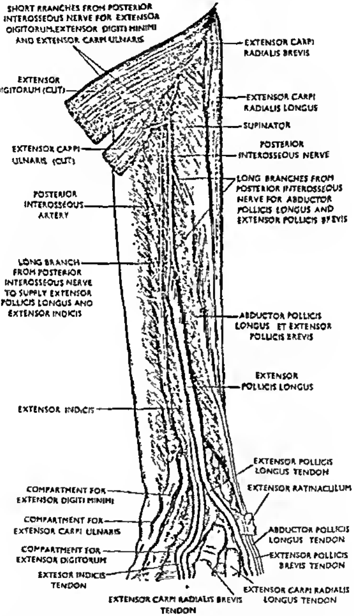


Fig. 541. The back of the right forearm to show the deep muscles. From the dessection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

Nerve supply. It is supplied by the posterior interosseous branch of the radial nerve (C. 7 and 8).

Actions. It extends the metacarpo-phalangeal joint of the thumb and also acts as an abductor of the same.

Opponens pollicis. This is one of the short muscles of the thumb but it is not attached to the phalanges of the same.

Origin. It arises from the superficial aspect of the flexor retinaculum and from the crest of the trapezium.

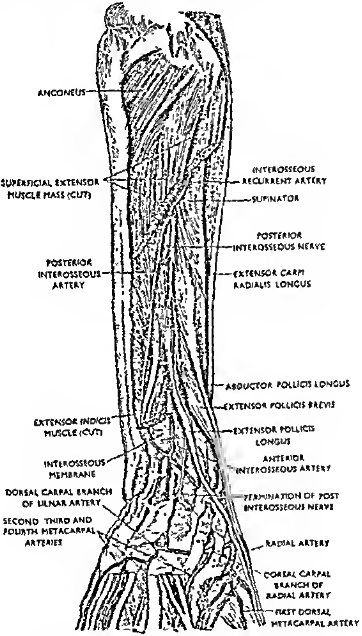


Fig. 542. The dorsum of the right forearm and a part of the hand to show the deep muscles and the posterior interosseous nerve and the dorsal carpal networks. From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

Insertion. It is inserted into the radial border and to the antero-lateral surface the shaft of the first metacarpal bone.

Nerve supply. It is supplied by a branch from the median nerve (C. 8 and T. 1).

Actions. As it is inserted into the first metacarpal bone its action is limited to le carpometacarpal joint of the thumb. It is the medial rotator and adductor of

the thumb and these two movements occur simultaneously and are collectively called the movement of opposition of the thumb. The mechanism of the movement is that the opponens pollicis draws the radial border of the first metacarpal bone towards the ulnar side and rotates it medially so that the pulp of the thumb faces the palmar surface of the finger. The true antagonist to it is the extensor pollicis longus which, though a true extensor, can cause abduction and lateral rotation of the thumb. The other short muscles of the thumb are attached to phalanges of the thumb and they work out the movement of opposition through the metacarpophalangeal joint.

Muscles attached to the phalanges of the little finger. The following muscles are attached to the phalanges of the little finger.

To the palmar aspect and ulnar side of the proximal phalanx	Abductor digiti minimi. Flexor digiti minimi.
To the palmar aspect and radial side of the proximal phalanx	Fourth palmar interosseous muscle and 4th lumbrical.
To the palmar aspect of the middle phalanx.	Flexor digitorum (sublimis) superficialis.
To the palmar aspect of the distal phalanx.	Flexor digitorum profundus.
To the dorsal aspect of the base of the proximal phalanx	Extensor digiti minimi.
To the dorsal aspect of the middle phalanx.	Extensor digitorum (Intermediate slip).
To the dorsal aspect of the distal phalanx.	Extensor digitorum (Collateral slip).

(1) **Abductor digiti minimi.** It arises from the anterior surface of the pisiform bone, from the tendon of the flexor carpi ulnaris and also from the pisohamate ligament.

Nerve supply. It is supplied by the deep branch of the ulnar nerve (C. 8 and T. 1).

Actions. It abducts the proximal phalanx of the little finger.

(2) **Flexor digiti minimi.** It arises from the convex surface of the hook of the hamate bone and also from the anterior aspect of the flexor retinaculum.

Nerve supply. It is supplied by the deep branch of the ulnar nerve (C. 8 and T. 1).

Action. It flexes the proximal phalanx of the little finger.

(3) **Extensor digiti minimi.** It arises from the lateral epicondyle of the humerus in common with other extensor muscles and also from the interosseous membrane.

Nerve supply. It is supplied by the posterior interosseous nerve (C. 7).

Action. It extends the proximal phalanx of the little finger.

Opponens digiti minimi. This is one of the short muscles of the little finger but it is not attached to its phalanges. It arises from the medial aspect of the hook of the hamate bone and from the medial aspect of the flexor retinaculum. It is inserted into the medial aspect of the shaft of the fifth metacarpal bone.

Nerve supply. It is supplied by the deep branch of the ulnar nerve (C. 8 and T. 1).

Actions. It is the adductor of the little finger and flexor of the fifth metacarpal bone at the carpometacarpal joint.

Muscles attached to the phalanges of the index finger—

To the palmar aspect and radial side of the proximal phalanx.	First lumbricalis.
To the palmar aspect and ulnar side of the proximal phalanx.	Second palmar interosseous
To the dorsal aspect and radial side of the proximal phalanx.	First dorsal interosseous.
To the palmar aspect of the middle phalanx.	Flexor digitorum superficialis (sublimis).

To the palmar aspect of the distal phalanx.	*Flexor digitorum profundus.*
To the dorsal aspect of the middle phalanx.	Extensor digitorum.
To the dorsal aspect of the distal phalanx.	Extensor digitorum.

The muscles attached to the phalanges of the middle finger:

To the palmar aspect and radial side of the proximal phalanx.	Second lumbricalis.
To the dorsal aspect and radial side of the proximal phalanx.	Second dorsal interosseous.
To the dorsal aspect and ulnar side of the proximal phalanx.	Third dorsal interosseous.
To the palmar aspect of the middle phalanx.	*Flexor digitorum superficialis.*
To the dorsal aspect of the second phalanx.	Extensor digitorum.
To the palmar aspect of the distal phalanx.	Flexor digitorum profundus.
To the dorsal aspect of the distal phalanx.	Extensor digitorum.

All the above muscles have already been described.

The muscles attached to the phalanges of the ring finger:

To the palmar aspect and radial side of the proximal phalanx.	Third lumbricalis. Third palmar interosseous.
To the dorsal aspect and ulnar side of the proximal phalanx.	Fourth dorsal interosseous.
To the palmar aspect of the second phalanx	Flexor digitorum superficialis.
To the dorsal aspect of the second phalanx.	Extensor digitorum.
To the palmar aspect of the distal phalanx.	*Flexor digitorum profundus.*
To the dorsal aspect of the distal phalanx.	Extensor digitorum.

Neurological value of the muscles of the upper extremity:

(1) *Muscles supplied by the radial nerve:*
- (*a*) Triceps brachii (Cervical 6, 7 and 8).
- (*b*) Lateral half of brachialis (Cervical 7).
- (*c*) Brachioradialis (Cervical 5 and 6).
- (*d*) Extensor Carpi radialis longus (Cervical 6 and 7).
- (*e*) Anconeus (Cervical 7 and 8).

(2) *Muscles supplied by the posterior interosseous nerve:*
- (*a*) Extensor carpi radialis brevis (Cervical 6 and 7).
- (*b*) Supinator (Cervical 5 and 6).
- (*c*) Extensor carpi ulnaris (Cervical 7).
- (*d*) Extensor digiti minimi (Cervical 7).
- (*e*) Extensor digitorum (Cervical 7).
- (*f*) Extensor indicis (Cervical 7).
- (*g*) Extensor pollicis longus (Cervical 7).
- (*h*) Extensor pollicis brevis (Cervical 7).
- (*i*) Abductor pollicis longus (Cervical 6 and 7).

(3) *Muscles supplied by the median nerve:*

From the nerve trunk:
- (*a*) Pronator teres (Cervical 6).
- (*b*) Flexor carpi radialis (Cervical 6).
- (*c*) Palmaris longus (Cervical 8).
- (*d*) Flexor digitorum superficialis (sublimis).

Through anterior interosseous nerve:
- (*a*) Lateral half of the flexor digitorum profundus (Cervical 7, 8 and thoracic 1).
- (*b*) Flexor pollicis longus (Cervical 8 and thoracic 1).
- (*c*) Pronator quadratus (Cervical 6 and 7).

Through terminal branches:
- (*a*) *Thenar muscles—abductor* pollicis brevis, *flexor pollicis brevis and* opponens pollicis.
- (*b*) First and second lumbricals.

(4) *Muscles supplied by the ulnar nerve:*
 (a) Flexor carpi ulnaris (Cervical 8 and thoracic 1).
 (b) Medial half of the flexor digitorum profundus.
 (c) Hypothenar muscles. (Abductor digiti minimi, flexor digiti minimi and opponens digiti minimi).
 (d) All the interosseous muscles of the hand.
 (e) Third and the fourth lumbricals.
 (f) Adductor pollicis.

(5) *Muscles supplied by the musculocutaneous nerve* (arm):
 (a) Biceps brachii (Cervical 5 and 6).
 (b) Coracobrachialis (Cervical 7).
 (c) Medial half of the brachialis (Cervical 5 and 6).

(6) *Muscles supplied by the circumflex nerve:*
 (a) Deltoid (Cervical 5 and 6).
 (b) Teres minor (Cervical 5).

(7) *Muscles supplied by the lower subscapular nerve:*
 (a) Subscapularis (Cervical 5 and 6).
 (b) Teres major (Cervical 5 and 6).

(8) *Muscles supplied by the suprascapular nerve:*
 (a) Supraspinatus (Cervical 5 and 6).
 (b) Infraspinatus (Cervical 5 and 6).

The pectoralis major et minor are both supplied by the lateral and medial pectoral nerves. The serratus anterior, latissimus dorsi, levator scapulae and the rhomboids are supplied by the nerves of the same name; the subscapularis in addition to the lower subscapular nerve receives the upper subscapular nerve.

MUSCLES OF THE THORAX

Muscles of the thorax. The following are the muscles of the thoracic wall:
(1) Intercostalis Externus.
(2) Intercostalis Internus.
(3) Transversus Thoracis.
 (a) Sternocostalis.
 (b) Subcostalis.
 (c) Intercostalis Intimi.
(4) Levator Costarum.
(5) Serratus Posterior Superior.
(6) Serratus Posterior Inferior.

Morphology of the muscles of the thoracic wall. The muscles of the thoracic wall belong to the muscles of the body wall that surround the coelomic cavity during embryonic life. They are arranged into three layers corresponding to the three layers of muscles on the abdominal wall, namely external oblique, internal oblique and transversus abdominis.

The *external layer* corresponding to the external oblique is specialised to be broken into several components which establish connection with the upper limb and the muscles in this group are the pectorals, serratus anterior and the rhomboids. The *intermediate layer*, which corresponds to the internal oblique muscle, is split into two layers by the developing rib and consists of the external intercostal and the internal intercostal, the fibres of which intersect each other. The *inner layer* consists of sternocostalis, intercostalis intimi and the subcostalis and they correspond to transversus abdominis of the abdomen.

Intercostalis Externus. Each muscle fills the space between the two ribs and its fibres are directed downwards and forwards. Posteriorly it extends up to

tubercle of the rib where it blends with the posterior surface of the superior costo-transverse ligament. The intercartilaginous portion of the muscle is replaced by membranous fibres and is known as *external (anterior) intercostal membrane*. Each muscle takes its origin from the lower border of the rib above and is inserted to the upper border of the rib below. Levator costarum overlaps its posterior part whereas in the lower part of the thorax obliquus externus abdominis overlaps the anterior part of the muscle. These three muscles, that is, the external intercostal, the external oblique and the levator costarum have the same direction, common nerve supply and are derived from a common source.

Nerve supply. It is supplied by the corresponding intercostal nerve.

Action. It elevates the rib.

Intercostalis Internus. Each muscle fills the space between two ribs lying deep to the intercostalis externus. It extends from the lateral border of the sternum to the angle of the rib from where it is replaced by membranous fibres—the *internal (posterior) intercostal membrane* which extends backwards to the anterior surface of the superior costo-transverse ligament with which it is blended. It arises from the floor of the costal groove of the rib above and is inserted to the inner lip of the upper border of the rib below. Its fibres are directed opposite to that of the external intercostal muscle, i.e. upwards and backwards and the two muscles cross each other like a St. Andrew's cross. Each intercostal muscle has two layers of muscle fibres and the inner layer is known as the intercostalis intimi.

Nerve supply. Same as above.

Action. It depresses the rib.

Transversus Thoracis. Consists of *intercostalis intimi*, *subcostalis* and the *sternocostalis*.

(*a*) *Intercostalis intimi.* They constitute the deeper planes of fibres of the intercostalis internus muscle. They are very ill defined in the upper spaces and gradually become well developed in the lower spaces. They only occupy the middle two-fourths of an individual space. Each arises from the upper border of the costal groove and is inserted to the upper border of the rib below along with the intercostalis internus muscle. They separate the intercostal vessels and nerves from the costal pleura.

(*b*) *Subcostalis.* It consists of both muscular and aponeurotic fasciculi and well developed only in the lower part of the thorax. Each muscle arises from the inner surface of the rib above near its angle and is inserted into the inner surface of the second or the third rib below. Its fibres have the same direction as the intercostalis internus. It separates the intercostal vessels and nerves from the costal pleura.

(*c*) *Sternocostalis muscle.* It arises from the posterior surface of the (1) xiphoid process of the sternum, (2) from the lower part of the posterior surface of the body of the sternum and (3) from the inner ends of the fifth, sixth, and seventh costal cartilages. Its fibres pass upwards and lateralwards and are inserted into the second, third, fourth, fifth and sixth costal cartilages close to their costal ends. The lowest fibres of the muscle are horizontal and are continuous below with the transversus abdominis.

Nerve supply. It is supplied by second, third, fourth, fifth and sixth intercostal nerves.

Actions. It draws down the costal cartilages to which it is attached.

Levator Costarum. They are twelve in number. Each arises from the tip of the transverse process of the vertebra above and is inserted to the upper border and the outer surface of the rib below between its angle and the tubercle. The first one arises from the tip of the transverse process of the seventh cervical vertebra.

Nerve supply. It is supplied by the intercostal nerve.

Actions. It rotates the neck of the rib forward and acts as a lateral flexor and rotator of the vertebral column.

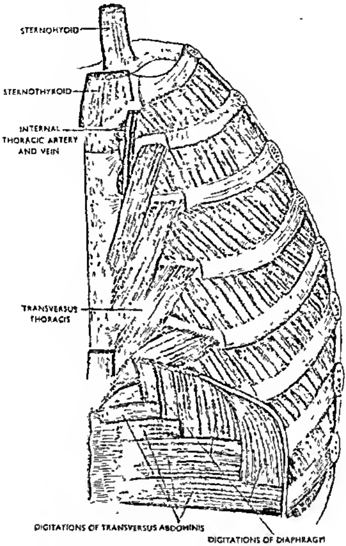


Fig 543. The inner aspect of the anterior chest wall. Seen from behind.

Serratus posterior superior. It is a quadrilateral-shaped muscle situated at the upper and posterior part of the thorax. It arises from the lower part of the ligamentum nuchae, the spinous process of the seventh cervical and the first, the second and third thoracic vertebrae and the supraspinous ligament. It is inserted by four fleshy digitations into the upper border and the outer surface of the second, third, fourth and fifth ribs, a little beyond the angle.

Nerve supply. Second, third and fourth intercostal nerves.

Actions. Elevator of the upper ribs.

Serratus posterior inferior. It is situated at the lower part of the back of the thorax. It arises by aponeurotic fibres from the spinous process and the supraspinous ligaments of the last two thoracic and the first, second and the third

lumbar vertebrae. Its fibres are directed upwards and laterally and it is inserted by four fleshy digitations to the lower border and the outer surface of the lower four ribs.

Nerve supply. Anterior primary rami of the 9th, 10th, 11th and 12th thoracic nerves.

Actions. It is the depressor of the lower four ribs. It assists in the action of the diaphragm by fixing the lower four ribs.

MUSCLES OF THE ABDOMEN

Obliquus externus abdominis. *Origin.* It arises from the outer surfaces and the lower borders of the lower eight ribs. Its upper four or five slips interdigitate with the serratus anterior while its lower slips interdigitate with the latissimus dorsi. From its extensive origin its fibres descend downwards, forwards and medially and are inserted as follows:

Insertion. Its lowest fibres descend vertically downwards and are inserted into the anterior half of the outer lip of the ventral segment of the iliac crest by fleshy fibres. Its highest fibres are inserted to the xiphoid process by aponeurotic fibres; its middle fibres pass downwards, forwards and medially and end in a broad aponeurosis which is inserted into the linea alba, anterior superior iliac spine, the pubic tubercle, front of symphysis pubis and to the pectineal line. The portion extending from the anterior superior iliac spine to the pubic tubercle is folded on itself and forms the *inguinal ligament.* The portion attached to the pectineal line forms the *pectineal part of the inguinal ligament.* Some of the fibres from the pectineal line are reflected obliquely upwards and medially and by passing through the linea alba become continuous with the fellow of the opposite side to form the *reflected part of the inguinal ligament.*

Opposite the pubic crest it presents a deficiency in its aponeurosis and forms the *superficial inguinal ring* which is hidden from view by the attachment of a thin fascia around the opening and is known as the *external spermatic fascia.* It is triangular in shape and presents two crura or roots and an arched limb. The two crura are connected with each other by an arched band of fibres which interlace each other and form the intercrural fibres. The spermatic cord and the ilioinguinal nerve in case of male, and the round ligament of the uterus and the ilioinguinal nerve in female, pass through the superficial inguinal ring.

Nerve supply. It is supplied by the lower six intercostal, last thoracic, ilioinguinal and iliohypogastric nerves.

Actions. Acting together they compress the abdominal viscera and raise the intra-abdominal pressure and thus help in expulsion of faeces, urine and the foetus from the uterus in case of female. When the thorax is fixed it raises the pelvis upwards. When the pelvis is fixed it depresses the thorax and thus helps in the respiration.

Superficial inguinal ring. The superficial inguinal ring is a deficiency in the aponeurosis of the external oblique muscle and is situated immediately above the pubic tubercle. It forms the outlet of the inguinal canal and transmits the spermatic cord and the ilioinguinal nerve in case of male, and the round ligament of the uterus and the ilioinguinal nerve in case of female.

The aponeurosis of the external oblique as it passes to the pubis splits up into two diverging bundles—one passes to the pubic tubercle and is then continuous with the medial part of the inguinal ligament while the other is attached to the front of the symphysis pubis where its fibres decussate with the fellow of its opposite side.

It is triangular in shape and its apex is directed upwards and laterally. Its base corresponds to the pubic crest and its margins formed by the diverging bands of the aponeurosis, are called the *crura.* They are two in number—superior and inferior. The *superior crus* is directed upwards and medially and is more or less straight and is attached to the front of the symphysis pubis. The *inferior crus* is

directed downwards and laterally and is attached to the pubic tubercle. The spermatic cord or the round ligament of the uterus rests on this crus. The two crura are connected with each other by arched bands of fibres which are concave downwards and form the *intercrural fibres*. The margins of the opening give attachment to a thin layer of fascia known as the external spermatic fascia which is prolonged on to the spermatic cord and hides the opening from view.

INGUINAL LIGAMENT. It is formed by the folded lower border of the aponeurosis of the obliquus externus abdominis and extends from the pubic tubercle to the anterior superior iliac spine. From its medial attachment to the pubic tubercle it is reflected backwards to be attached to the medial one inch of the pectineal line and forms the *pectineal part of the inguinal ligament* and the portion that is reflected from the pectineal line to the linea alba to become continuous with the fellow of the opposite side, forms the *reflected part of the inguinal ligament*. In its course it forms a concavity superiorly and convexity inferiorly due to the fascia lata being attached to its inferior aspect. The space below the inguinal ligament is known as the pelvifemoral space through which the false pelvis communicates with the thigh.

Pectineal part of the inguinal ligament. The pectineal part of the inguinal ligament is formed by that portion of the inguinal ligament which is reflected from the pubic tubercle to the pectineal line. It is about one inch in length and is triangular in shape. Its apex corresponds to the pubic tubercle, while its base forms a free concave margin which is directed laterally and forms the medial boundary of the femoral ring. Its inguinal border is continuous with the medial end of the inguinal ligament while its pectineal border is attached to the medial one inch of the pectineal line Its superior or abdominal surface is directed upwards, backwards and medially and forms in this situation the medial part of the floor of the inguinal canal. The spermatic cord in the male and the round ligament of the uterus in the female rests on this surface. Opposite its base this surface gives attachment to the transversalis fascia. Its attachment to the pectineal line lies anterior to the attachment of the conjoined tendon and the transversalis fascia. Its femoral or inferior surface is directed downwards. A fibrous band extends lateralwards from the base of the pectineal part of the inguinal ligament along the pectineal line and is known as the *pectineal ligament* or the *ligament of Cooper*.

Relations. Superficially it is covered by the skin, superficial fascia and the deep layer of the superficial fascia of the abdomen. Opposite its mid-point it is crossed superficially by the superficial epigastric vessels. The superficial circumflex iliac vessels pass laterally in front of it along its lateral half. The superficial inguinal lymph glands are related to its lower border.

Deep to it the pelvi-femoral space is occupied by the *iliacus, psoas* and the *pectineus* from lateral to medial side. The lateral *cutaneous nerve* of the *thigh* enters the thigh between the anterior superior and anterior inferior iliac spines. Passing in front of the psoas major are the *femoral vessels* and the *femoral branch* of the *genitofemoral nerve* which lies lateral to the femoral artery. The femoral nerve enters the thigh through the groove between the iliacus and the psoas. The transversalis fascia in front and ilio-pectineal fascia behind descend to the thigh under the inguinal ligament and are applied to the femoral vessels to form the femoral sheath below the inguinal ligament. Lateral to the femoral vessels the fascia iliaca and transversalis fascia are fused together and are attached to deep surface of the inguinal ligament. Coursing along the deep surface of the lateral half of the inguinal ligament is the *deep circumflex iliac vessels* which intervene between the iliac and transversalis fasciae and ultimately it escapes from this fascial sheath by piercing the latter fascia. The lower fibres of the transversus abdominis, internal oblique and the cremaster muscle also take their origin from the deep surface of the inguinal ligament.

Internal Oblique Muscle. ***Origin.*** It lies deep to the external oblique muscle and superficial to the transversus abdominis. It arises from the anterior two-thirds of the ventral segment of the intermediate lip of the iliac crest, from the

upper surface of the lateral two-thirds of the inguinal ligament and from the posterior lamella of the lumbar fascia in the angle between the iliac crest and the sacrospinalis muscle.

Insertion. Its posterior fibres ascend vertically upwards and are inserted by three or four digitations into the lower margin of the last three or four ribs close to their anterior extremity. Its middle fibres, that is, those fibres from the anterior part of the iliac crest, pass upwards, forwards and medially and end in a broad aponeurosis which reaching the lateral border of the rectus abdominis splits up into two lamellae; one passes in front of the rectus while the other passes behind it.

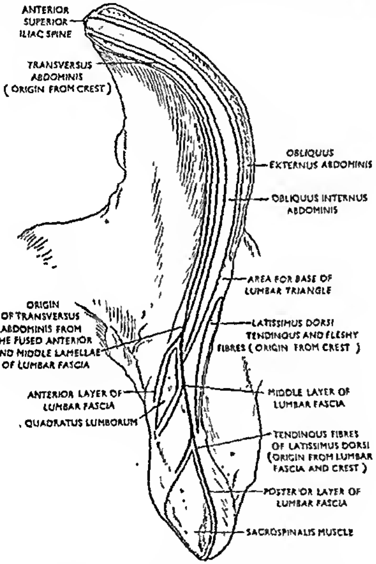


Fig. 544. The top view of the right iliac crest to show the muscular attachments.

The anterior lamella blends with the external oblique aponeurosis while the posterior lamella blends with transversus abdominis and then they reunite at the medial margin of the rectus and finally are inserted into the linea alba. Its anterior or lowest fibres arch over the lateral part of the inguinal canal and then end in an aponeurosis which blends with the aponeurosis of the transversus abdominis to form the *conjoint tendon* which meets its fellow of the opposite side in the linea alba and then by extending downwards it is inserted into the pubic crest and the pectineal line.

Some of the lowest fibres of the internal oblique are prolonged over the spermatic cord to form the *cremaster muscle.*

Nerve supply and action. Same as external oblique.

Cremaster. *Origin.* The cremaster muscle is continuous with the lowest fibres of the internal oblique muscle and takes its origin from the middle of the inguinal ligament. Its fibres descend along the lateral aspect of the spermatic cord and emerge through the superficial inguinal ring along with the spermatic cord. They form a series of loops which are festooned by a thin layer of fascia known as the *cremasteric fascia* which forms an investment for the cord also.

Insertion. The highest fibres of the loop end into a delicate tendon which is inserted into the pubic tubercle and the crest.

Nerve supply. It is supplied by the genital branch of the genito-femoral nerve (L 1 and 2).

Actions. By its contraction the cremaster muscle raises the testis towards the superficial inguinal ring. Structurally it is a striated muscle but functionally it is an involuntary muscle.

Applied Anatomy. *Cremasteric reflex.*

Transversus abdominis. It lies deep to the internal oblique muscle and its fibres run transversely and hence it is called the transversus abdominis.

Origin. It arises from the anterior two-thirds of the inner lip of the iliac crest, from the deep surface of the lateral one-third of the inguinal ligament, from the lumbar fascia (in the interval between the iliac crest and the last rib) and by fleshy digitations from the inner surface of the lower six ribs interdigitating with the diaphragm muscle.

Insertion. The majority of the fibres end in an aponeurosis which is broadest at the level of the umbilicus. Above this level its muscle fibres gradually approach the median plane and immediately below the xiphoid process its muscle fibres reach the median plane where it interdigitates with the fellow of its opposite side. The aponeurosis of the transversus abdominis blends with the posterior lamella of the internal oblique muscle and passing behind the rectus abdominis is inserted into the linea alba up to a point midway between the umbilicus and the symphysis pubis. Below this level the aponeurosis blends with internal oblique aponeurosis and turns downwards along the lateral margin of the rectus abdominis to form the *conjoint tendon.* Its inguinal fibres, as they turn upwards and medially, end in a free border which arches over the deep inguinal ring and form the roof of the inguinal canal in this situation.

Nerve supply and action. Same as that of the oblique muscles.

Conjoint Tendon. The fibres of origin of the transversus abdominis and the internal oblique muscles from the inguinal ligament arch over the deep inguinal ring and then end in a common tendon known as the *conjoint tendon.* The conjoint tendon passes deep to the superficial inguinal ring and is inserted into the pubic crest and the medial part of the pectineal line. By passing deep to the superficial inguinal ring the conjoint tendon helps to compensate for the weakness caused by the superficial inguinal ring.

Lumbar Triangle. It is an intermuscular triangle situated behind the posterior border of the obliquus externus abdominis and above the highest point of the iliac crest. It is bounded in front by the posterior border of the obliquus externus abdominis and behind by the latissimus dorsi muscle. The base is formed by the iliac crest, and the apex, by the union of the latissimus dorsi with the obliquus externus abdominis muscle. The floor is formed by the obliquus internus abdominis. It is covered only by the skin and superficial fascia.

It forms a weak point in the posterior abdominal wall and occasionally a lumbar hernia may descend through it.

Inguinal canal. The inguinal canal is an oblique space connecting the deep with the superficial inguinal ring. The *deep inguinal ring* is a circular opening in the transversalis fascia on the lateral side of the inferior epigastric artery, situated about half an inch above the mid-point between the anterior superior iliac spine and the symphysis pubis and it transmits the vas deferens in the male and the round ligament of the uterus in the female from the abdominal cavity. The *superficial inguinal* ring is an oblique opening in the aponeurosis of the external oblique muscle and just corresponds to the pubic crest and the tubercle.

The inguinal canal is about 4 cm. long, oblique in direction and runs almost parallel to the inguinal ligament. It is placed about half an inch above the inguinal ligament. It has got an anterior and a posterior wall, a roof and a floor.

The *anterior wall* is formed by the skin, the superficial fascia and the aponeurosis of the external oblique muscle throughout its entire extent, and along its lateral-third, in addition, are the fleshy fibres of the internal oblique muscle. The *posterior wall* is formed by the peritoneum, the extra-peritoneal connective tissue and the transversalis fascia throughout the whole length, and by the conjoint tendon and the reflected inguinal ligament along the medial-third in addtion. Thus it is evident that the posterior wall is stronger along its medial part having the conjoint tendon and the reflected inguinal ligament as additional coverings whereas the anterior wall is stronger laterally owing to the addition of the internal oblique fibres.

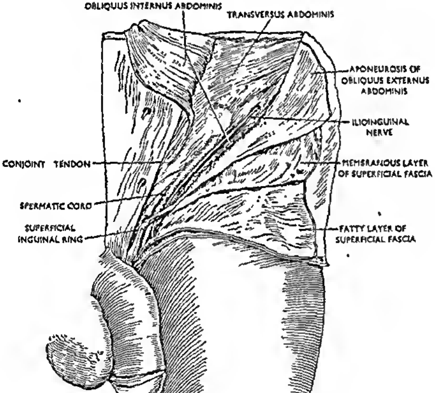


Fig. 545. The dissection of the left inguinal canal. From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

Roof. It is formed by the arched fibres of the transversus abdominis and the internal oblique muscles.

Floor. It is formed by the union of the transversalis fascia with the inguinal ligament and at its medial end by the pectineal part of the inguinal ligament.

Contents. *Spermatic cord* and the *ilioinguinal nerve* in case of male and the *round ligament of the uterus* and the *ilioinguinal nerve* in case of female.

Applied Anatomy. The inguinal canal is a deficiency in the anterior abdominal wall through which direct and oblique variety of inguinal hernia may descend. The weakness is compensated by the ***oblique direction of the canal*** and ***by the situation of the deep and superficial rings at different points***, because in any rise of the intra-abdominal pressure the posterior wall of the canal is pushed against the anterior wall and thereby obliterates the canal. During increased intra-abdominal pressure the *cremaster muscle contracts* and thereby forms a sort of plug in the canal thus compensating for natural weakness. The oblique variety of inguinal hernia traverses through the deep inguinal ring whereas the direct variety enters the inguinal canal by pushing the posterior wall of the canal in front of it.

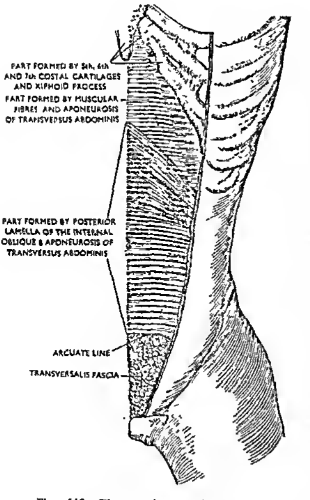


Fig. 546. The posterior wall of the rectus sheath. (Diagrammatic).

Rectus Sheath. The rectus sheath is an aponeurotic envelope for the rectus abdominis muscle.

Mode of Formation. The mode of formation and the constitution of the sheath are not uniform throughout the entire extent of the rectus abdominis muscle. Thus it can be divided into four different parts, each having a distinctive construction.

(1) *From a point three inches below the angle between the xiphoid process and the costal margin to midway between umbilicus and symphysis pubis.* Here the internal oblique muscle reaching the lateral border of the rectus abdominis splits up into two lamellae, anterior and posterior. The anterior lamella passes in front of the rectus abdominis muscle, and blends with the aponeurosis of the external oblique whereas the posterior lamella blends with the aponeurosis of the transversus abdominis muscle and passes posterior to the rectus muscle and finally the two lamellae reaching the medial border of the rectus muscle are joined together and then are inserted into the linea alba. Thus it is found that the anterior wall of the sheath in this region is formed by the aponeurosis of the external oblique muscle and the anterior lamella of the internal oblique muscle and the posterior wall is formed by the posterior lamella of the internal oblique and the aponeurosis of the transversus abdominis muscle. The posterior wall of the sheath at its lowest point, that is, midway between the umbilicus and the symphysis pubis, ends in an arched border the concavity of which is directed downwards and is known as the *arcuate line*.

(2) *Below the point midway between the umbilicus and the pubis.* Opposite this situation the internal oblique aponeurosis does not split but together with the transversus abdominis passes in front of the rectus muscle. Thus here the anterior wall is formed by the aponeurosis of the external and internal oblique and the transversus abdominis, the posterior wall being only formed by the transversalis fascia on which the muscle rests.

(3) *For the first three inches below the costo-xiphoid angle.* The internal oblique aponeurosis fails to reach in this situation because it terminates by insertion into the costal arch in this level. Therefore, the posterior wall of the sheath in this situation is formed by the musculo-aponeurotic fibres of the transversus abdominis. The muscle fibres of the latter muscle almost reach the median plane; in other words, this part of the posterior wall is partly muscular.

(4) *Above the costal margin.* Here both the internal oblique and transversus abdominis aponeurosis do not extend above the costal arch. The only aponeurosis that extends above the costal arch is that of the external oblique muscle. Therefore in this region the anterior wall being formed only by the external oblique aponeurosis and the posterior wall being deficient, the muscle rests partly on the xiphoid process and mostly on the cartilages of the 5th, 6th and 7th ribs against which the rectus muscle is inserted.

The anterior wall of the sheath is adherent to the rectus muscle at three points opposite the three tendinous intersections of the rectus muscle, that is, one opposite to the xiphoid process, one opposite to the umbilicus and the third in between the former two. The *posterior wall of the sheath is quite free from the muscle throughout its entire extent* and the wall is separated from the peritoneum by the transversalis fascia.

Contents:

Muscles. Rectus abdominis extends from the costal arch to the symphysis pubis. Pyramidalis is occupying the lower and medial part of the sheath below the umbilicus.

Vessels. Superior epigastric branch of the internal mammary artery is anastomosing with the inferior epigastric branch of the external iliac artery above the umbilicus. Lower six intercostal and the subcostal branches of the descending thoracic aorta reach the sheath by piercing its posterior wall. The veins are corresponding to the arteries.

Nerves. Lower six intercostal and subcostal nerves enter the sheath by piercing the posterior wall of the sheath.

Rectus Abdominis. *Origin.* It arises by two heads—*lateral and medial.* The lateral head arises from the lateral part of the pubic crest while the medial head takes its origin from the condensed mass of fibro-areolar tissue in front of the symphysis pubis. The two heads soon unite together and then ascend vertically upwards up to their points of insertion.

Insertion. Its medial fibres are inserted in the anterior aspect of the xiphoid process of the sternum. Its lateral fibres divide into three slips which are inserted into the front of the cartilages of the fifth, sixth and seventh ribs respectively.

Nerve supply. It is supplied by the lower six intercostal nerves and the last thoracic nerve.

Action. Acting from below it depresses the thorax and in continued action flexes the vertebral column (lumbar vertebra), as in rising from the recumbent to sitting posture. Acting from above it raises the pelvis upwards. Acting together they depress the anterior abdominal wall. Acting singly it flexes the trunk laterally wards. To sum up, its actions are:

(1) Compressor of the abdominal viscera.
(2) Depressor of the thoracic wall.

(3) Flexor of the trunk.
(4) Lateral flexor of the trunk.

Pyramidalis. It arises by tendinous fibres from the anterior surface of the body of the pubis immediately below the pubic crest and by ligamentous fibres from the front of the symphysis. Its fibres converge towards the median plane to be inserted into the linea alba opposite a point midway between the symphysis pubis and the umbilicus.

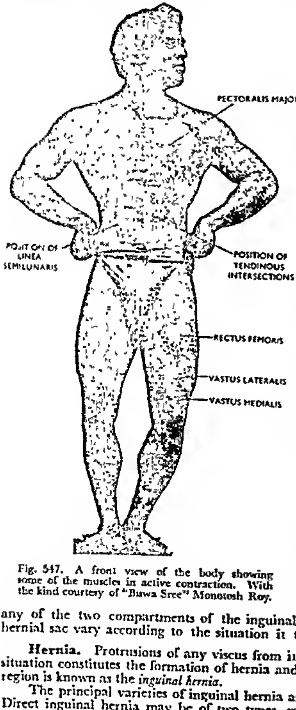


Fig. 547. A front view of the body showing some of the muscles in active contraction. With the kind courtesy of "Biswa Sree" Monotosh Roy.

Nerve supply. It is supplied by the last thoracic nerve.

Action. It is the tensor of the linea alba.

Inguinal triangle. This is a trianglar area on the peritoneum situated in the lower part of the anterior abdominal wall. Its base is formed by the inguinal ligament, apex by the meeting of the inferior epigastric artery with the lateral border of the rectus abdominis, lateral border by the inferior epigastric artery and the medial border by the lateral margin of the rectus abdominis muscle. The obliterated umbilical artery runs upwards from opposite the middle of its base towards the apex and divides the triangle into a medial and a lateral part. The medial part lies in between the obliterated umbilical artery and the median umbilical ligament of the bladder and is known as the *supra-vesical fossa.* The lateral part lies in between the obliterated umbilical artery and the inferior epigastric artery and is known as the *medial inguinal fossa.* Lateral to the inguinal triangle is the deep inguinal ring which lies at the lower part of the *lateral inguinal fossa.*

Direct variety of inguinal hernia may descend through any of the two compartments of the inguinal triangle and the coverings of the hernial sac vary according to the situation it traverses.

Hernia. Protrusions of any viscus from its normal situation to an abnormal situation constitutes the formation of hernia and that which occurs in the inguinal region is known as the *inguinal hernia.*

The principal varieties of inguinal hernia are of two types—*Oblique* and *direct.* Direct inguinal hernia may be of two types, medial or lateral according as they transverse the area in the inguinal triangle.

The oblique inguinal hernia lies on the lateral side of the inferior epigastric artery while the direct variety lies on its medial side.

Coverings of the oblique inguinal hernia. As the oblique inguinal hernia passes through the deep inguinal ring its hernial sac formed by the peritoneum receives first the internal spermatic fascia, then in the inguinal canal, it receives the cremasteric muscle and fascia, at the superficial inguinal ring it receives the external spermatic fascia and lastly, when it comes out of the superficial inguinal ring and descends into the scrotum, it receives the superficial fascia and the skin.

Coverings of the direct inguinal hernia. The medial variety of direct inguinal hernia at first pushes the peritoneum, extra-peritoneal connective tissue and the transversalis fascia in front of it, then the conjoint tendon and the reflected inguinal ligament. Then when it comes out of the superficial inguinal ring it receives the external spermatic fascia and in the scrotum it receives the superficial fascia and the skin.

The lateral variety nf the direct inguinal hernia has the following coverings: (1) Peritoneum, (2) Extra-peritoneal tissue, (3) Transversalis fascia, (4) Cremasteric muscle and fascia, (5) External spermatic fascia and (6) the superficial fascia and the skin.

Difference between the oblique and the direct inguinal hernia:

Oblique Variety	Direct Variety
1. It passes through the lateral inguinal fossa	1. It passes through the medial inguinal fossa and the supravesical fossa.
2. It enters the inguinal canal through the deep inguinal ring.	2. It enters the inguinal canal by pushing its posteror wall in front of it.
3. The inferior epigastric artery lies on its medial side.	3. The inferior epigastric artery lies on its lateral side.
4. Difference in its coverings as mentioned above.	4. Difference in the coverings as mentioned above.

When the flat and the recti muscles have been removed the anterior abdominal wall will be seen to be formed by a thin glistening, transparent cloth-like structure known as the *peritoneum*. Lying superficial to the peritoneum is a thin layer of areolar tissue on which there lies a delicate fascia known as the *transversalis fascia*. On a general view the peritoneum, extraperitoneal connective tissue and the transversalis fascia will be found as a single layer of membranous structure but when a light incision is given the transversalis fascia retracts from the cut margin and it is seen to be a distinct layer of fascia which is spread on the loose extraperitoneal connective tissue.

Transversalis fascia. It is the general investing fascia on the anterior abdominal wall situated beneath the transversus abdominis muscle and in front of the extraperitoneal connective tissue. *Above*, it is continuous with the fascia covering the undersurface of the diaphragm. *Below*, opposite the iliac crest, it is attached to the whole length of the inner lip of the iliac crest between the iliacus and the transversus abdominis. Opposite to the lateral half of the inguinal ligament it is attached to the under-surface of the same ligament and is fused with the fascia iliaca. Opposite to the femoral vessels it is attached to the under-surface of the inguinal ligament and then is continued downwards in front of the femoral vessels. Medial to the femoral vessels it is fused with the deep aspect of the conjoint tendon and is finally attached to the pectineal line. *Posteriorly* it is fused with the lumbar fascia (anterior layer).

POSTERIOR ABDOMINAL WALL

The posterior abdominal wall is an osseo-musculo-fibrous wall and extends from the inner surfaces of the lower ribs to the pelvic brim.

The bony parts of the posterior abdominal wall is formed medially by the five lumbar vertebrae with their transverse processes and the inter-vertebral

laterally and above, it is formed by the inner surfaces of the lower ribs, and laterally and below, by the iliac fossa.

The muscular part of the posterior abdominal wall above the iliac crest is formed from medial to the lateral side by the psoas major et minor muscles, intertransversus, quadratus lumborum and the transversus abdominis muscle and below the iliac crest it is formed laterally by the iliacus and medially by the psoas major muscle.

The fibrous part is formed by the lumbar fascia and the fascia iliaca.

Muscles of the posterior abdominal wall:

Psoas major muscle. It is that portion of the iliacus muscle which has migrated above the iliac crest.

Origin. It arises by fleshy fibres from the discs between twelfth thoracic and fifth lumbar vertebrae, from the adjoining portions of the bodies of these vertebrae, from the tendinous arches that connect the upper and lower borders of the middle of the sides of upper four lumbar vertebrae, and from the anterior surfaces and lower border of the transverse processes of the five lumbar vertebrae. It forms a fusiform belly which descends on the side of the vertebral column and passes through the hollow between the anterior inferior iliac spine and the iliopubic eminence.

Insertion. It forms a tendon which passes in front of the capsule of the hip joint from which it is separated by a bursa. It receives majority of the fibres of the iliacus muscle and is inserted into the summit of the lesser trochanter of the femur.

Nerve supply. It is supplied by branches from the second, third and fourth lumbar nerves.

Action. It acts in combination with iliacus and is the flexor of the hip joint and the pelvis. It also acts as medial rotator of the thigh when the foot is off the ground.

Relations. The psoas major muscle lies lateral to the lumbar vertebrae and descends in front of the lumbar transverse processes, intertransverse muscles, medial edge of the quadratus lumborum, ala sacralis, lateral part of the converging slope of the iliac fossa and the front of the capsule of the hip joint. Opposite the first three lumbar vertebrae the kidney with its capsule and the surrounding adipose tissue overlaps its lateral side with the descending colon in front on the left side and the ascending colon in front on the right side. Lower down the iliacus muscle lies on its lateral side. The inferior vena cava on the right side, and the inferior mesenteric vein on the left side, ascend in front of the muscle in the retro-peritoneal tissue. The ureter and the testicular or ovarian vessels descend downwards whereas renal and colic vessels pass laterally in front of it on both sides. The external iliac vessels lie medial to it in the pelvis whereas the femoral artery lies in front of it below the inguinal ligament. The psoas minor muscle also descends downwards in front of it. The lumbar plexus of nerves lies within its substance.

Psoas minor. This muscle is present only in few cases and lies in front of the psoas major muscle. It arises from the bodies of the twelfth thoracic and the first lumbar vertebrae and from the intervening disc between them. It is inserted into the pectineal line and the iliopubic eminence by a tendon.

Action. It is a weak flexor of the trunk and tensor of the fascia iliaca.

Nerve supply. It is supplied by branches from the first and second lumbar nerves.

Iliacus. *Origin.* It arises from the upper two-thirds of the iliac fossa, from the inner lip of the iliac crest and from the iliolumbar and the anterior sacroiliac ligaments. It forms a traingular muscle and its fibres converge to a hollow between the anterior inferior iliac spine and the iliopubic eminence to form a tendon which lies lateral to the psoas major muscle.

Insertion. Majority of its fibres are inserted into the tendon of the psoas major muscle and a few fibres are inserted into the base of the lesser trochanter and extending into the shaft for about one inch.

Nerve supply. It is supplied by branches from the femoral nerve (L. 2 and 3).

Action. It acts in combination with the psoas major muscle and its actions are identical with the latter.

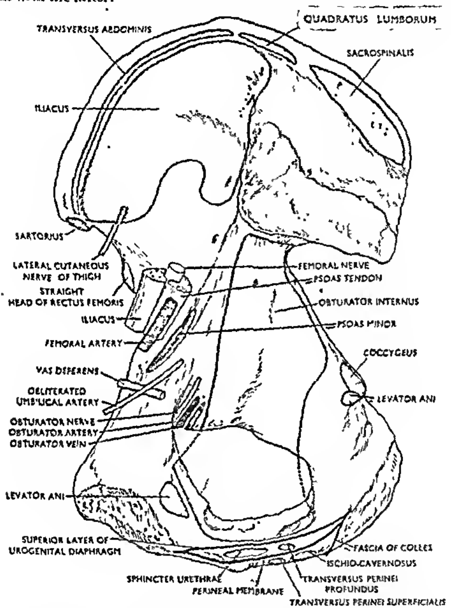


Fig. 548. The internal aspect of the right hip bone to show the attachments and some of the relations.

Fascia Iliaca. The fascia iliaca is a strong fascial sheet that covers the iliacus and psoas major muscles. *Above* and *laterally* it is attached to the inner lip of the iliac crest. *Medially* being reinforced by the aponeurosis of the psoas minor it passes in front of the psoas major muscle and is attached to the iliopectineal line in front and to the pelvic brim up to the ala sacralis behind. Its posterior attachment being weaker it does not produce any liping on the ala sacralis. *This part of the fascia is pierced by the obturator nerve, iliolumbar artery and the anterior primary rami of the fourth lumbar nerve.* Above the pelvic brim it is continuous with the psoas fascia. *Below* and *medially* it is continuous with the pectineal fascia to form the ilio-pectineal fascia which forms the posterior wall of the femoral sheath and is separated from the inguinal ligament and the transversalis fascia by the femoral vessels and the deep inguinal lymph vessels.

Psoas fascia. It is continuous *below* with the fascia iliaca and *above* it is thickened to form the medial arcuate ligament from which the diaphragm arises. *Medially* it is attached to the bodies and intervertebral discs of the upper three lumbar vertebrae. *Laterally* it fuses with the fascia covering the quadratus lumborum (anterior lamella of the lumbar fascia) and is attached to the tips of the transverse processes of the upper three lumbar vertebrae. Medially it is pierced by the lumbar arteries and rami communicantes of the lumbar spinal nerves. Below and anteriorly it is pierced by the genitofemoral nerve.

Applied Anatomy. The collection of pus under the psoas fascia either from caries spine of the dorsal region or of the lumbar region takes the course either of the psoas fascia or of the structures that pierce it. The pus from the dorsal region tracks within this fascia by passing under the medial arcuate ligament. Taking the course of the psoas fascia the pus may reach the lesser trochanter of the femur (insertion of the psoas) and cause a swelling in the femoral triangle. The fascia is pierced by the lumbosacral nerve trunk, obturator nerve and some of the lumbar vessels and nerves. Taking the course of the lumbar nerves it may reach the flank and point in the lumbar triangle or in the anterior abdominal wall. Following the obturator and the femoral nerve it may reach the thigh and taking the course of the sciatic nerve it may reach the gluteal region, then into the back of the thigh and the popliteal region under the fascia lata and the popliteal fascia and ultimately it may reach even to the back of the heel under the fascia cruris.

Quadratus lumborum. It is a quadrilateral-shaped muscle that fills up the gap between the last rib and the iliac crest. It arises by aponeurotic fibres from the posterior one-third of the inner lip of the iliac crest and from the iliolumbar ligament. It is inserted by fleshy fibres to the medial half of the anterior surface and the lower border of the last rib and by tendinous fibres to the tips of the transverse processes of the upper four lumbar vertebrae.

Nerve supply. It is supplied by the last thoracic and by the branches from the upper three or four lumbar nerves.

Actions. Acting singly it is the lateral flexor of the trunk and acting together, it is the weak extensor of the trunk. It fixes the last rib and helps in the inspiration.

Relation. It is covered in front by the anterior lamella of the lumbar fascia and is in relation with the kidney and colon (ascending on the right side and descending on the left side). It is covered above by the diaphragm muscle and is overlapped medially by the psoas major muscle. Lying in front of its covering fascia from above downwards are the subcostal vessels and the subcostal, iliohypogastric and the ilioinguinal nerves which intervene between its covering fascia and the renal fascia on the posterior aspect of the kidney.

Intertransversarii (Laterals). These are short muscles that extend between the borders of the transverse processes of the two adjacent vertebrae. They are supplied by anterior primary rami of the spinal nerves.

Diaphragm muscle. It is a dome-shaped musculo-aponeurotic partition that intervenes between the thorax and the abdomen and separates the two cavities from each other (complete separation of the two cavities is a feature of the mammalian characteristic). Its superior surface is concavo-convex having a rounded cupula on each side on which the base of the corresponding lung rests, and a central depressed area on which the heart lies and forms the floor of the thoracic cavity. The right cupula ascends to a level which corresponds to a line joining a point on the fifth rib half an inch below the right nipple to a point on the back half an inch below the inferior angle of the right scapula. The left cupula corresponds to a line joining a point on the left fifth interspace one inch below the left nipple to a point on the back one inch below the inferior angle of the left scapula. The central depressed area corresponds to a line joining a point on the xiphi-sternal articulation in front to the eighth thoracic spine on the back. The inferior surface of the diaphragm is deeply concave and forms the roof of the abdominal cavity.

Origin. The diaphragm arises in front from the xiphoid process of the sternum, from the lumbar vertebrae behind, and at the sides, from the inner aspects of the ribs and costal cartilages and hence its fibres of origin can be grouped accordingly as *sternal*, *costal* and *vertebral*.

The *sternal fibres* arise by two muscular slips from the back of the xiphoid process of the sternum.

The *costal fibres* take their origin by five or six fleshy digitations from the inner surfaces of the lower six ribs and cartilages on each side interdigitating with the transversus abdominis muscle.

The *vertebral fibres* arise from the lateral and medial arcuate ligaments on each side and from the right and left crura.

The *lateral arcuate ligament* is derived from the fascia covering the quadratus lumborum and is formed by an arched thickened band in the fascia which passes across the upper part of the quadratus lumborum muscle. It is attached medially to the anterior aspect of the transverse process of the first lumbar vertebra and laterally to the anterior surface of the twelfth rib.

The *medial arcuate ligament* is an arched thickened band in the fascia covering the upper part of the psoas major muscle. It is attached laterally to the anterior aspect of the transverse process of the first lumbar vertebra and medially to the anterior aspect of the body of the first lumbar vertebra. Medially each medial arcuate ligament is continuous with the corresponding crus of the diaphragm.

The *crura of the diaphragm.* The crura of the diaphragm are tendinous below at their origin and fleshy above. At their origin the tendinous fibres become fused with the anterior longitudinal ligament. The medial margin of each crus is tendinous and they become continuous with each other above, in front of the abdominal aorta to form the *median arcuate ligament.* The *right crus* is longer and stouter than the left and arises from the front of the bodies of the upper three lumbar vertebrae and the corresponding intervertebral fibroeartilaginous discs. The *left crus* arises from the front of the bodies of the upper two lumbar vertebrae and from the intervertebral disc between them.

Relations of the crura—Right crus. *Anteriorly* the right crus is in relation with the right kidney, right suprarenal gland, head of the pancreas and is crossed in front by the right renal artery, right middle suprarenal and right inferior phrenic arteries. The inferior vena cava ascends upwards in front of it being separated by the right suprarenal, renal and inferior phrenic arteries and the right coeliac ganglion. *Posteriorly* the right crus lies in front of the bodies of the upper three lumbar vertebrae together with the intervertebral discs and the anterior longitudinal ligament and the cisterna chyli, vena azygos and the upper two right lumbar arteries intervene between it and the anterior longitudinal ligament.

Left crus. *Anteriorly* the left crus is related to the left coeliac ganglion, left middle suprarenal, renal and inferior phrenic arteries, the left suprarenal gland, left kidney and the body of the pancreas. *Posteriorly* the left crus lies in front of the bodies of the upper two lumbar vertebrae together with the intervertebral disc and the anterior longitudinal ligament. The first left lumbar artery intervenes between it and the anterior longitudinal ligament.

Each crus is pierced by the greater, lesser and the lowest splanchnic nerves and the left crus in addition is pierced by the hemiazygos vein. The abdominal aorta together with the coeliac axis intervenes between the two crura.

Insertion. From the different sources of origin the fibres converge centrally and are inserted to a central tendon.

The *sternal fibres* are the shortest of all because of the more anterior position of the central tendon and are inserted into the anterior leaflet of the central tendon. The *costal fibres* are inserted into the antero-lateral border of the lateral leaflet of the central tendon. The *vertebral fibres* are the longest of all and are inserted into the posterior concave border of the central tendon. The fibres from the right crus

spread out as they ascend upwards and split up to enclose an elliptical opening, th *oesophageal opening*. The fibres from the left crus similarly spread. Some of it fibres from its medial margin pass in front of the aorta to the right crus but thes fibres never come to the formation of the oesophageal opening.

Central Tendon. It is the dense, strong, roughly cresentic aponeurotic membrane situated in between the cupola, into which the muscular fibres of the diaphragm ar inserted. Although it goes by the name "central" tendon it is not central in positio but it is placed more anteriorly and consequently the sternal fibres become the shortest of all. Its posterior border is concave while its anterior border, though presents three prolongations, is convex in general outline. The anterior prolongations are leaf-like and when seen together the central tendon resembles a trefoil leaf consisting of one anterior and two lateral leaflets or lobes.

Structurally it is a densely felted aponeurosis consisting of closely interoven tendinous fibres. At its centre is a thick nodule at which bundles of fibres decussate like the letter X resembling a St. Andrew's Cross. The central tendon is pierced by inferior vena cava and the opening lies on the right side of the cross.

Relations—Pleural and pericardial. The superior surface of the diaphragm is covered by parietal pleura (diaphragmatic pleura) except its central region where the pericardium is adherent to it and for this, when the diaphragm is isolated from the body and we are to determine the upper and lower surfaces, the adherent pericardium on the upper surface is a guide.

N B The intimate relation of the pericardium with the central tendon of the diaphragm indicates the common source of origin of the two structures from the septum transversum in embryonic life Both the caudal portion of the pericardium and the central tendon of the diaphragm are derived from the septum transversum.

Peritoneal. The inferior surface is covered by the parietal peritoneun except the region of the crura and opposite the bare areas of the liver where the diaphragm is adherent to the latter.

General. The *upper surface* of the diaphragm is related to the base of the lung on either side and the inferior surface of the heart with the pericardium. On either side, beyond the base of the lung, the upper surface is related to the chest wall from which it is separated by the costodiaphragmatic recess. It is also related to the cellular tissue of the anterior and posterior mediastinum.

The *lower surface* from right to the left is related to the convex surface of the liver, fundus of the stomach, diaphragmatic surface of the spleen and the left colic flexure.

In addition the diaphragm is related to the structures that pierce it at different places. The relations of the crura have already been described.

Openings in the diaphragm. There are three large openings—vena caval, oesophageal and aortic and several smaller openings.

Vena caval opening. It is square-shaped and is situated opposite the level of fibro-cartilage between the eighth and ninth thoracic vertebra and a little to the right of the median plane. The opening passes through the central tendon of the diaphragm.

It transmits the inferior vena cava and a few branches from the right phrenic nerve.

Oesophageal opening. It is oval in shape and is situated a little to the left of the median plane opposite to the level of the tenth thoracic vertebra. It is formed between the decussating fibres of the right crus of the diaphragm. The decussating fibres appear to act as a sphincter for the cardiac end of the stomach and prevents regurgitation of food into the oesophagus during respiration.

It transmits the oesophagus, the right and left vagus nerves, and the oesophageal branch of the left gastric artery with the accompanying vein.

Aortic opening. It is an osseo-aponeurotic aperture, rounded in shape, situated exactly in the median plane opposite the level of the twelfth thoracic vertebra. The

aorta does not pierce the diaphragm but passes behind the median arcuate ligament in between the two crura.

It transmits the descending thoracic aorta, the thoracic duct and the azygos vein in order from left to right.

N.B. The aortic opening is an osseo-aponeurotic opening and in fact the aorta does not pierce the diaphragm at all. It is bounded in front by thin median arcuate ligament and behind by the 12th *thoracic vertebra*. The opening being an osseo-aponeurotic one and also being placed in between two crura, the aorta can maintain quite a free circulation in spite of the alternate contraction and relaxation of the diaphragm muscle. Free circulation of blood through the aorta would have been impossible if it would pass through an intra-muscular opening. The vena caval opening enlarges during inspiration due to the pull of the surrounding fleshy fibres and consequently its content is hurried on to the heart. The condition of the oesophageal opening during respiration has already been said.

Smaller openings in the diaphragm:

(1) One is situated between the xiphoid slip and that from the seventh costal cartilage. It transmits the superior epigastric vessels.

(2) One is placed between the slips from the seventh and eighth costal cartilages. It transmits the musculo-phrenic vessels.

(3) One is situated in between each pair of the remaining slips. Each one transmits the intercostal vessels and nerves to the abdominal wall.

(4) Each crus is perforated by the greater, lesser and the lowest splanchnic nerves.

(5) The sympathetic trunk passes behind the medial arcuate ligament.

(6) The subcostal vessels and nerves pass behind the lateral arcuate ligament.

(7) The inferior hemiazygos vein pierces the left crus of the diaphragm in addition to the splanchnic nerves.

Nerve supply. The diaphragm is supplied by (1) the phrenic nerve (C. 3, 4 and 5) which is both motor and sensory. It is the only motor nerve supplying the whole of the diaphragm. Its sensory filaments supply the central portion of the diaphragm. (2) The lower six intercostal nerves which are sensory nerves for the diaphragm supply the peripheral portions of the same muscle. (3) Some branches from the coeliac ganglion also supply the diaphragm and they are probably concerned with the tone of the muscle.

Artery supply. The pericardiaco-phrenic and the musculo-phrenic branches of the internal mammary artery, the superior phrenic branch of the thoracic aorta, the inferior phrenic branch of the abdominal aorta and the lower intercostal branches of the descending thoracic aorta supply the diaphragm.

The veins are corresponding to the arteries.

The lymph vessels from the diaphragm end into diaphragmatic, pre- and *lateral aortic group of lymph nodes. The lymphatics of the opposite surfaces* communicate freely with each other.

Actions. (1) *It is the chief muscle of inspiration and acts by mainly increasing the vertical diameter and partly the anteroposterior diameter of the thoracic cavity.* This is brought about as follows: The twelfth rib is fixed by the quadratus lumborum and the other lower ribs are steadied by the serratus posterior inferior. Taking a fixed point at the lower ribs and at the vertebral column, the diaphragm contracts and as a result, the abdominal viscera are pushed down causing increase in the vertical diameter of the thoracic cavity; with continued contraction it takes the fixed point above at the central tendon and slightly elevates the lower ribs, and together with them, the upper ribs and the sternum are also pushed forward and thereby causing increase in the antero-posterior diameter of the thoracic cavity.

(2) It *helps in expulsive forces* as in defaecation, urination, parturition, coughing and sneezing by its sustained contraction at the end of the inspiratory phase.

(3) The fibres of the right crus that decussate around the oesophageal opening act as sphincter for the oesophagus and prevent regurgitation of the food from the stomach to the oesophagus.

(4) It aids circulation of blood by enlarging the vena caval opening and thereby speeding up flows through the inferior vena cava during its contraction.

Development. Developmentally diaphragm can be divided into 4 parts, ventral, dorsal, and two lateral parts. The ventral part is developed from the septum transversum, and the dorsal part from the mesoderm of the dorsal mesentry. The lateral parts of the diaphragm are derived from the pleuro-peritoneal membrane and from that portion of the mesoderm of the adjoining body wall (L.B. Arey)

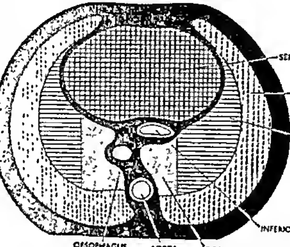


Fig. 519. The development of the diaphragm. (Schematic).

which has been detached from the rectus and transversus muscle sheet and have acquired attachment to the lower six ribs. The different developmental components fuse together to complete the formation of the membranous diaphragm. Striated muscle fibres of the diaphragm are derived from the pre-muscle masses opposite the third, fourth and fifth cervical segments. The septum transversum with pre-muscle masses at its caudal part migrates from the cervical region caudally together with its nerve (phrenic nerve) and thus contributes to the formation of the diaphragm.

Applied Anatomy. (1) Due to developmental error the vertebro-costal angle of the diaphragm may fail to close up leaving a gap through which hernial protrusion may occur, and this form of herniation is known as *congenital diaphragmatic hernia.* In this type of hernia there is usually no hernial sac. (2) Sometimes the oesophageal hiatus remains enlarged and the oesophagus does not form a close fitting with the hiatus and as a result a hernial protrusion may also occur through this gap giving rise to a condition known as *hiatal hernia* (Acquired). (3) When the diaphragm is ruptured due to trauma traumatic hernia may also occur. (4) In case of paralysis of the phrenic nerve the dome of the diaphragm on the affected side rises up considerably giving rise to a condition known as *eventration of the diaphragm.* (5) Due to communication of the sub-pleural and sub-peritoneal lymphatics infection from one cavity may pass to the other. (6) A collection of pus under the diaphragm is known as *sub-diaphragmatic Abscess.* By resecting the tenth rib and elevating the costo-diaphragmatic recess of the pleura the abscess may be opened through the diaphragm.

MALE PERINEUM

Roughly speaking, perineum constitutes the bottom of the trunk and in an erect posture, it occupies the interval between the two thighs. It corresponds to the outlet of the true pelvis and is bounded in front by the subpubic angle, behind by the coccyx, in front and laterally, by the ischio-pubic rami and the ischial tuberosity, and behind and laterally, by the sacrotuberous ligament.

For practical purposes the whole of the perineal region, is divided into two arts by passing a line in front of the anus joining the two ischial tuberosities. The rea in front of this line is known as the *urogenital triangle* and the area behind this is nown as the *anal triangle*.

Jrogenital triangle. *Boundary*:

Base. It corresponds to an imaginary line that passes in front of the anus and onnects the two ischial tuberosities.

Apex. By the subpubic angle.

Sides. By the ischio-pubic rami.

If a vertical section is made through the urogenital region, the structures that occupy the different starta, from without inwards, are as follows:

(1) Skin.
(2) Adipose layer of the superficial fascia.
(3) Membranous layer of the superficial fascia (fascia of Colles).
(4) Layer of superficial perineal muscles and the superficial perineal vessels and nerves (scrotal vessels and nerves).
(5) Perineal membrane.

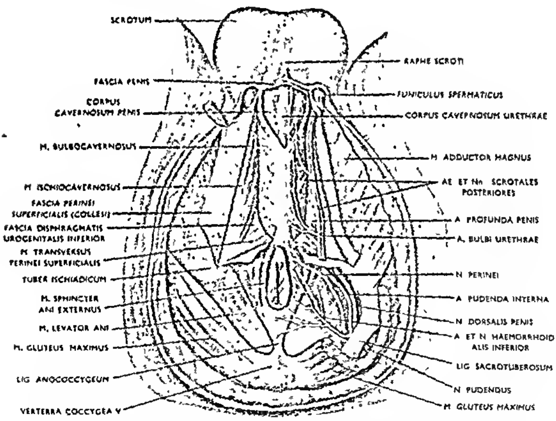


Fig. 550. The male perineum. *Both the superficial perineal pouches and the ischiorectal fossae have been exposed.* With the kind permission from: Callanders Surgical Anatomy 2nd edition 1939, W. B. Saunder's company: Philadelphia and London.

(6) Layer of deep perineal muscles, the deep perineal vessels and nerves (internal pudendal vessels and the pudendal nerve), the bulbo-urethral gland with its duct and the membranous portion of the urethra (in male), and urethra and vagina (in female).
(7) Parietal layer of the pelvic fascia (superior layer of urogenital diaphragm).

General fascial arrangement. The adipose layer of the superficial fascia lies beneath the skin and forms the general investing layer and *gains no bony attachment* but is continuous with the superficial fascia of the adjoining areas. The deep membranous layer of the superficial fascia (fascia of Colles), the perineal membrane (inferior layer of the urogenital diaphragm) and the superior layer of the urogenital diaphragm gain bony attachments on either side to the ischio-pubic rami and by doing so they enclose two spaces amongst them and are known as the perineal pouches. The superior and the inferior layers of the urogenital diaphragm with the muscles enclosed between them form a septum or partition that stretches across the urogenital triangle and closes the pelvic outlet. This fibro-muscular partition is known as the *urogenital diaphragm.*

Fascia of Colles or the membranous layer of the superficial fascia of the perineum. The fascia of Colles is the deep layer of the superficial fascia of the urogenital triangle. It is strong and membranous and covers the urogenital triangle which is bounded on either side by the ischio-pubic rami, posteriorly, by an imaginary line connecting the anterior part of the two ischial tuberosities, and anteriorly, by the sub-pubic angle.

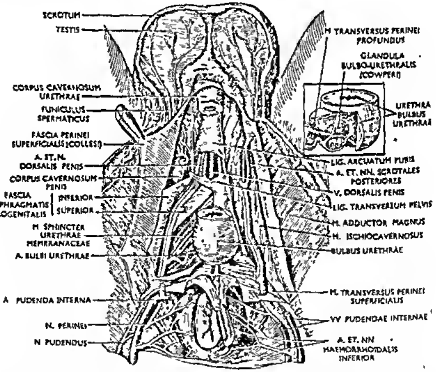


Fig. 551. The pouches of the perineum and the ischiorectal fossae. With the kind permission from : Callanders Surgical Anatomy 2nd edition 1939, W. B. Saunder's company : Philadelphia and London.

Attachments. Posteriorly it winds round the superficial transverse perineal muscle and is blended with the base of the perineal membrane; on either side it is attached to the ischio-pubic rami; anteriorly it is continuous with the superficial fascia of the scrotum (dartos tunic), which in turn, is continuous with the fascia covering the root of the penis and with the fascia of Scarpa (deep layer of the superficial fascia of the abdomen). Superiorly it is in relation with the contents of the superficial pouch of the perineum.

√**Superficial pouch of the perineum.** The superficial pouch of the perineum is the interfascial space bounded superiorly by the perineal membrane and

inferiorly by the fascia of Colles. The space is closed from all sides except anteriorly where it follows the line of reflection of the dartos tunic. It is incompletely divided into two compartments by an imperfect median septum extending from the deep surface of the fascia of Colles to the bulbospongiosus muscle.

Contents:

(A) *Muscles*:

(1) Ischiocavernosus—Lying against the ischio-pubic rami.
(2) Bulbospongiosus—Occupying the median plane.
(3) Transversus perinei superficialis—Each passing transversely opposite the base of the urogenital triangle and joins with the fellow of its opposite side, immediately above the anus, in the perineal body.
(4) Crura of the penis—It arises from the inferior ramus of the pubis and soon joins with the bulbospongiosus to form the root of the penis.

(B) *Vessels*:

(1) Scrotal vessels—They lie in the space between the ischiocavernosus and bulbospongiosus and intervene between the two scrotal nerves.

(C) *Nerves*:

(1) Scrotal nerves—They are two in number and lie on either side of the scrotal vessels.

(D) *Other structures*:

(1) Spongy urethra—It is surrounded by the bulbospongiosus.

Structures piercing the perineal membrane. The perineal membrane is pierced by the following structures:

At the base. Scrotal vessels and nerves.

At the marign close to the apex. The deep and the dorsal arteries of the penis.

At the centre:

(1) Urethra (membranous part) about one inch below the symphysis pubis.
(2) Ducts of the bubo-urethral gland.
(3) Arteries to the bulb of the penis or the vestibule in case of female.
(4) Urethral artery.
(5) Vagina in case of female.

Besides these, the muscular branches from the perineal nerve also pierce the perineal membrane.

Urogenital diaphragm. The urogenital diaphragm is a fibro-muscular partition which stretches across the urogenital triangle and shuts the anterior part of the pelvic outlet, and intervenes between the pelvic cavity and the perineum. It consists of two muscles, transversus perenei profundus and the sphincter urethrae, and two fasciae, the superior layer of the urogenital diaphragm and the perineal membrane. These two muscles enclosed by the two layers of fasciae (perineal membrane and the superior layer of the urogenital diaphragm) constitute the formation of the urogenital diaphragm. √

Superior fascia or the superior layer of the urogenital diaphragm. The superior layer of the urogenital diaphragm lies deep to the muscles of the urogenital diaphragm and is derived from that portion of the pelvic fascia which covers the obturator internus (obturator fascia). After covering the obturator internus it is attached to the ischio-pubic rami and then passes medially and reaching the median plane, it becomes continuous with the fellow of its opposite side. Posteriorly it is fused with the perineal membrane. Anteriorly it is continuous with the sheath of the prostate.

Inferior layer of the urogenital diaphragm or perineal membrane. The perineal membrane or the inferior layer of the urogenital diaphragm is a triangular fascia and lies superificial to the deep perineal muscles. On either side it is attached to the ischio-pubic rami. Posteriorly it blends with the superior layer of the urogenital diaphragm. Anteriorly it is fused with the latter and is thickened to form the *transverse perineal*

ligament which stretches across the sub-pubic angle. A small gap between it and the inferior pubic ligament transmits the deep and dorsal vessels of the penis or clitoris.

Transversus perinei profundus. It arises from the pelvic surface of the ramus of the ischium and runs horizontally to the median plane where it interlaces its fibres with the fellow of its opposite side and is inserted into the perineal body (central tendon of the perineum).

Sphincter urethrae. It arises from the pelvic surface of the ramus of the ischium and pubis where they meet each other and is inserted around the membranous urethra. It consists of *external* and *internal fibres*. The external fibres, as they approach the median plane, split into anterior and posterior groups of fibres which pass in front of and behind the membranous portion of the urethra and end by blending with the corresponding fibres of the opposite side. The *internal fibres* constitute circular fibres that surround the membranous portion of the urethra.

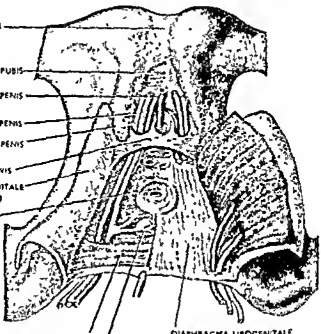


Fig. 552. The male perineum. The deep pouch has been exposed. With the kind permission from: Callanders Surgical Anatomy 2nd edition 1939, W. B. Saunder's company, Philadelphia and London.

The superior and inferior layers of the urogenital diaphragm enclose a space between them, the *deep pouch of the perineum* which, in addition to transversus perinei profundus and sphincter urethrae, contains the following structures:

(1) *Vessels.* Internal pudendal vessels; artery to the bulb or vestibule.

(2) *Nerves.* Dorsal nerve of the penis or clitoris.

(3) *Muscles.* Already mentioned.

(4) *Other structures.* Membranous portion of the urethra; bulbo-urethral glands, and vagina in case of female.

Anal Triangle. *Boundary*:

Base. It is formed by the imaginary line that passes in front of the anus and connects the two ischial tuberosities.

Apex. By the coccyx.

Sides. By the sacrotuberous ligaments and the inferior margin of the gluteus maximus muscle.

The posterior part of the pelvic outlet, that is, that portion of the pelvic outlet which lies opposite the anal triangle, is closed up in the recent state by a fibro-muscular partition, the *pelvic diaphragm.* This fibro-muscular septum stretches from the lower part of the lateral wall of the true pelvis and descends downwards and medially so as to fuse together around the anus in the median plane. Due to the obliquity of the pelvic diaphragm, spaces are formed on either side between the inferior surface of the pelvic diaphragm and the lower part of the lateral wall of the true pelvis and are known as the ischiorectal fossae. Each fossa is filled up mostly by fat in the recent state and forms a pad on either side of the anal canal and the anus.

Ischiorectal fossa. The ischiorectal fossa is the interval between the pelvic diaphragm and the pelvic surface of the ischium. It is somewhat pyramidal in shape with its apex directed upwards and the base downwards. Each measures about 2 inches in length, 1 inch in breadth and 2 inches in depth. Its lateral wall is vertical whereas its medial wall slopes downwards and medially.

Boundary:

Laterally. It is formed by the obturator internus with its covering fascia and the ischium.

Medially. Its medial wall is formed by the levator ani, sphincter ani externus and the anal fascia.

Anteriorly. It is bounded by the transversus perinei superficialis.

Posteriorly. It is bounded by the posterior margin of the gluteus maximus and the sacrotuberous ligament.

Apex. It is formed by the junction of anal fascia and the obturator fascia.

Base or floor. It is formed by the skin and the superficial fascia.

The *superficial fascia of the ischiorectal fossa* covers the floor of the space and lies beneath the skin. While it stretches across the fossa it gives out numerous fasciculi which dip into the fossa and enclose lobulated masses of fat that fill up the ischiorectal fossa.

The *deep fascia of the ischiorectal fossa* lines the deepest portions of the fossa and as it does so, it forms a semilunar arch for which professor Elliot Smith designed it as *lunate fascia.* Medially it covers the fascia on the levator ani muscle, *i.e.* the anal fascia and ends by blending with the same at the lower end of the levator ani muscle. Laterally it covers the obturator fascia and is attached to the ischium. The internal pudendal vessels and pudendal nerve lie between these layers of fasciae and the interfascial canal thus formed is known as the *pudendal canal.* Anteriorly the fascia fuses with the urogenital diaphragm. The summit of the arch formed by the lunate fascia is known as the *tegmentum.* There is a space between this tegmentum and the apex of the fossa and is known as the *suprategmental space* which contains some fat.

From the distribution of the superficial and the deep fasciae of the ischiorectal fossa it is evident that they are separated from each other by a considerable distance which is a peculiar feature of the fascial dispositions of the ischiorectal fossa.

Contents:

(1) *Internal pudendal vessels* lie in the pudendal canal on the lateral wall of the fossa.

(2) *Pudendal nerve.* It divides into perineal nerve and dorsal nerve of the penis or clitoris of which the latter lies above the internal pudendal vessels and the former below it.

(3) *Scrotal nerves.* The perineal nerve divides into scrotal nerves and lies in the anterior part of the fossa.

(4) *Perineal branch of the fourth sacral nerve and the perforating cutaneous branch of the second and the third sacral nerves.* They lie posteriorly in the superficial fascia opposite the posterior margin of the gluteus maximus.

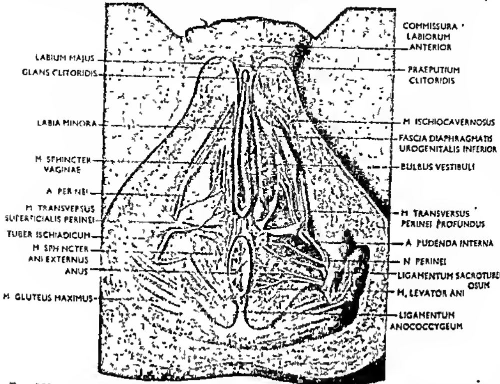


Fig 553 The female perineum. Both the superficial perineal pouches and the ischiorectal fossae have been exposed. With the kind permission from: Callanders Surgical Anatomy: 2nd edition 1939, W. B. Saunder's company; Philadelphia and London.

(5) *Inferior rectal vessels and nerves.* They pass transversely across the fossa from lateral to the medial wall.

(6) Large quantity of fat fills up the fossa and forms a tight pack around the lower part of the anal canal being separated from it by the pelvic diaphragm.

Surgical importance of ischiorectal fossa. Due to developmental errors hernial protrusion into the ischiorectal fossa is not uncommon. It is known that the levator ani arises, in front, from the back of the body of the pubis, and behind, from the pelvic surface of the ischial spine, and between these two points, from the tendinous arch of the pelvic fascia. Sometimes when the origin from the tendinous arch of the pelvic fascia is deficient a hiatus exists (hiatus of Schwalbe) in between its anterior and posterior fibres and a hernial protrusion through this gap usually comes into the ischiorectal fossa.

The fat in the ischiorectal fossa is predominantly fibrous in nature and consequently is in poor blood supply (Sir Frederick Treves). Due to its deficient blood supply it is the frequent seat of abscess formation. If the abscess forms superficial to the lunate fascia, the pus usually burrows between the external and internal sphincters and opens into the anal canal giving rise to fistula-in-ano. This is due to the fact that the lunate fascia and the anal fascia end opposite the lower end of the levator ani muscle and the portion of the anal canal that extends below this level is less protected due to the absence of both the fasciae and consequently this part becomes the path of least resistance. Collection of pus from one fossa may pass easily to the other, because the fat of both the fossae is continuous with each other both in front of and behind the anus and may give rise to a horse-shoe-shaped abscess or fistula.

The pelvic diaphragm or the pelvic floor. The pelvic diaphragm closes the posterior part of the pelvic outlet and separates the pelvic cavity from the ischio-rectal fossa and forms the pelvic floor. It consists of two muscles, levator ani and coccygeus which are covered superiorly by a thin layer of fascia, the superior layer of the pelvic diaphragm and inferiorly by another layer of fascia, the inferior fascia of the pelvic diaphragm (anal fascia). These two muscles enclosed by these two layers of fasciae constitute the pelvic diaphragm.

Anatomically the muscles of the pelvic diaphragm, coccygeus and levator ani, form two different components but morphologically they belong to a single corporate unit consisting of three main parts, namely, ischio-coccygeus, ilio-coccygeus and pubo-coccygeus. The ischio-coccygeus is the anatomical coccygeus and the ilio-coccygeus and the pubo-coccygeus together form the anatomical levator ani muscle.

Levator ani. This is a broad, muscular sheet which, with the fellow of its opposite side, forms the greater part of the pelvic diaphragm or floor and supports the pelvic viscera.

Origin. It arises, in front, from the pelvic surface of the body of the pubis, behind, from the inner aspect of the ischial spine, and in between these two points, from the tendinous arch of the pelvic fascia (the white line of the pelvic fascia).

Insertion. From its origin the fibres pass towards the median plane and are inserted in the following ways:

(1) The most anterior fibres (anterior part of pubo-coccygeus) pass backwards and downwards and are inserted into the perineal body. These fibres constitute the *levator prostatae* in the male, but in the female, they cross the sides of the vagina and form an important sphincter for the same (*sphincter vaginae*).

(2) The succeeding fibres (posterior part of pubo-coccygeus), pass downwards and backwards across the sides of the prostate and the upper end of the anal canal, and opposite the ano-rectal flexure, they turn medially and become continuous with the fellow of the opposite side and with the posterior fibres of the deep part of the sphincter ani externus; some of its fibres are lost on the wall of the anal canal. This part of the muscle is called the *pubo-rectalis*, the deeper fibres of which forms a U-shaped sling for the ano-rectal flexure from above.

(3) The remaining fibres (ilio-coccygeus) descend downwards, medially and backwards and are inserted into the sides of the last two segments of the coccyx and into the ano-rectal raphe stretching between the coccyx and the anus.

Nerve supply. It is supplied by a branch from the fourth sacral nerve and also by a branch from either the perineal or the inferior rectal nerve.

Relation. Its upper or superior surface is covered by the parietal layer of the pelvic fascia which separates it from the urinary bladder, rectum and parietal peritoneum in both the sexes, from the prostate and seminal vesicle in the male and from the vagina in the female. Its lower or perineal surface is covered by the anal fascia and forms the medial boundary of the ischiorectal fossa. Anteriorly the two muscles are separated from each other by a U-shaped gap through which anterior part of the prostate in the male, and vagina and urethra in the female pass Posteriorly its posterior border overlaps the anterior part of the coccygeus.

Coccygeus. This muscle is well-developed in the tailed animals and is called the "agitator caudae". With the progress of evolution this muscle has retrogressed considerably in man because he has no tail and the muscle is no longer required to act as a tail muscle. The sacrospinous ligament on its back is its degenerated portion.

Origin. It lies posterior to the levator ani muscle and is triangular in shape. It arises by its apex from the inner aspect of the ischial spine and the sacro-spinous ligament.

Insertion. It is inserted by its broad base into the sides of the first two segments of the coccyx and the last two pieces of the sacrum (Cunningham).

Nerve supply. It is supplied by branches from the fourth and the fifth sacral nerves.

Action. Both levator ani and coccygeus have the same action and they work in association as a single unit. Due to erect posture in man they are to support the weight of the pelvic viscera for which they are to remain in a state maintaining increased tone (postural tone). During increased intra-abdominal pressure they actively contract so as to draw the perineal body upwards and forwards and thus they prevent the prolapsing tendency of the pelvic viscera through the pelvic outlet. The puborectalis part of the muscle acts as a sphincter for the ano-rectal junction and during increased intra-abdominal pressure as in coughing, sneezing etc. it prevents incontinence of faeces. The sphincter vaginae acts as a sphincter for the vagina.

Comparative Anatomy. In pronograde mammals the pelvic outlet does not form the dependent part and therefore, they do not require the presence of a strong pelvic diaphragm but they have a tail to wag and the muscles of the pelvic diaphragm in man act as tail wagger (tail muscles) in them and consequently they gain attachment in the caudal vertebrae. For the same reason the perfect circumanal attachment in man greatly differs from that in those animals where both ventral and dorsal to the rectum, the muscles of the two sides are separated from each other by gaps. Moreover, in animals the levator ani gains its higher attachment in the pelvic brim whereas in man it migrates caudalwards to gain its secondary attachment in the pelvic wall. In orthograde animals, such as in man, the pelvic outlet being the dependent part, the need for a stronger diaphragm is a necessity. Therefore the ischio- and ilio-coccygei in man take over the function of a strong but a elastic diaphragm whereas the pubo-coccygei are specially adapted to have controlling influences over the anal canal and the vagina.

MUSCLES OF THE FRONT OF THE THIGH

Superficial fascia. It is the general investing fascia for the thigh and contains much adipose tissue in its meshes. It is not uniform in its thickness, thus in the region of the groin it is comparatively thicker and can be divisible into two layers, superficial and deep. The superficial layer is continuous above with the superficial fascia of the abdomen while the deep layer is more membranous and is fused with the deep fascia. In between the two layers of the superficial fascia there intervene the superficial group of inguinal lymph nodes, the great (long) saphenous vein and some of the superficial vessels and nerves. Opposite the saphenous opening the deep layer of the superficial fascia is attached to its margins thereby closing the opening. This portion of the deep layer of the superficial fascia is perforated by the superficial branches of the femoral artery, the great saphenous vein and some of the superficial lymphatics. Due to the presence of these openings this portion of the fascia presents a cribriform (seive-like) appearance and is known as the *Cribriform fascia*.

Fascia Lata. The fascia lata is the deep fascia of the thigh. The term 'lata' has been so implied because of its extensive distribution.

Attachment. Posteriorly and above, it is continuous with the deep fascia of the buttock and through that it is attached to the back of the sacrum, coccyx and the posterior part of the iliac crest. Above and laterally, it is fixed to the whole length of the outer lip of the iliac crest.

Anteriorly it is attached to the undersurface of the inguinal ligament and the pectineal line. Medially it is attached to the outer everted margin of the pubis and the ischium, the ischial tuberosity and sacrotuberous ligament. Below it is fixed at all the bony prominences around the knee joint, and is attached to the vertical margins of the patella, femoral condyles, tibial condyles and the head of the fibula. Below and posteriorly it is continuous with the popliteal fascia.

Distribution. The fascia lata invests all the muscles of the thigh and presents some distinctive characters in its mode of distribution. From its attachment to the anterior part of the iliac crest it descends downwards as a single layer to the upper border of the gluteus maximus muscle where it splits into two lamellae—superficial and deep, which enclose the gluteus maximus muscle. At the lower border of that muscle the two lamellae reunite to form a single layer which descends as far as the knee joint. The deep lamella, when traced upwards, is found to pass beneath the

tensor fasciae latae and is adherent to the capsular ligament of the hip joint. Anteriorly, immediately below the inguinal ligament, it consists of two distinct layers—superficial and deep. The superficial layer is attached to the undersurface of the whole length of the inguinal ligament and the pectineal line. From the latter attachment it descends downwards and laterally as a free falciform border forming the superior cornu of the saphenous opening which is a deficiency in the fascia lata in this region, and then turns upwards and medially forming the inferior cornu of the saphenous opening and becomes continuous with the deep layer.

The deep layer is fixed above to the pectineal line, medially to the margins of the pubic arch. It then passes beneath the femoral sheath and blends with the fascia covering the pectineus and the ilio-psoas. It is now evident that the superficial portion blends with the anterior wall of the femoral sheath whereas the deep layer joins with the posterior wall of the femoral sheath. The division of the fascia lata into superficial and deep layers in this region exists as far as the level of the distal border of the saphenous opening.

Saphenous opening. It is a deficiency in the fascia lata just below the medial end of the inguinal ligament and it measures about one and a half inches in length and half an inch wide. It has two cornua, superior and inferior. The superior one is formed by the superficial part of the fascia lata and the inferior one is formed by the deep layer of the fascia lata. It is roofed over by the cribriform fascia, a thin layer of the fascia derived from the deep layer of the superficial fascia which is pierced by the lymphatics, the long saphenous vein, the superficial epigastric artery and the superficial external pudendal artery.

The fascia lata in its course downwards through the thigh invests all the muscles of the thigh and sends out three distinct intermuscular septa which are attached to the linea aspera of the femur. The medial intermuscular septum separates the extensors from the adductors of the thigh; the lateral separating extensors from the flexors and the posterior one, which is the thinnest of all separates the adductors from the flexors.

Characteristic features. The most characteristic feature of the fascia lata is that it is not uniformly thick and strong. Thus medially it is very thin, so much so that muscles shine through this. Laterally it is very thick and strong and appears to be more aponeurotic than fascial in its character. The portion extending from the anterior part of the iliac crest to the lateral aspect of the knee joint is especially thickened to form two distinct layers which unite opposite the middle of the thigh to form a single layer and is known as the *ilio-tibial band or tract* of the fascia lata. Into this ilio-tibial band the tensor fasciae latae and the superficial fibres of the gluteus maximus are inserted. Its distal part therefore serves as an aponeurotic tendon by means of which the above two muscles gain their insertion into the lateral condyle of the tibia and the head of the fibula.

Surgical importance of fascia lata. It is known that the fascia lata is firmly attached to the bony prominences of the knee joint both in front and at the sides but behind, opposite the popliteal fossa, it is continuous with the popliteal fascia which is continuous below with the fascia cruris. Any collection of pus under fascia lata may extend posteriorly under cover of the popliteal fascia and subsequently it may reach as far as the heel under cover of the fascia cruris.

The muscles of the front of the thigh are as follows:

(1) Quadriceps femoris:
  (a) Rectus femoris.
  (b) Vastus medialis.
  (c) Vastus lateralis.
  (d) Vastus intermedius.

(2) Articularis Genu.
(3) Sartorius.
(4) Tensor fasciae latae.

Quadriceps femoris muscle. The quadriceps femoris muscle as the name implies "quadriceps" consists of four portions—rectus femoris, vastus lateralis, vastus medialis, and the vastus intermedius. The three vasti muscles (lateralis, medialis and the intermedius) clothe the lateral, medial and the anterior aspects of the femur and are more or less blended with each other. The rectus femoris forms

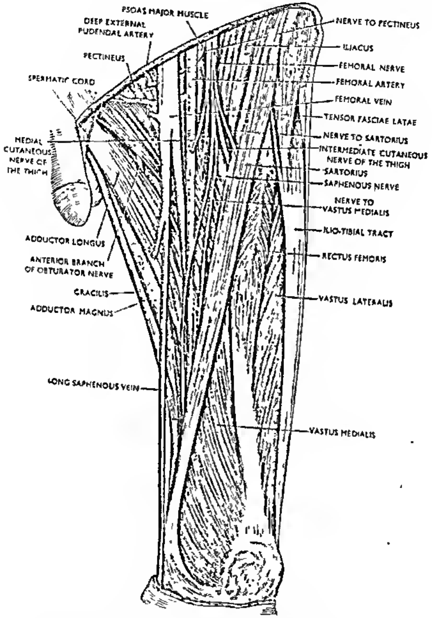


Fig. 554 The antero-medial aspects of the left thigh to show the muscles and some of the other structures. From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

a fusiform belly which is quite distinct from the rest of the quadriceps femoris and forms the most conspicuous straight muscle (rectus) lying in front of the thigh.

Rectus Femoris. *Origin.* It arises by two tendinous heads—straight and reflected heads. The *straight head* arises from the upper part of the antero-inferior iliac

spine while the *reflected head* arises from the groove on the upper part of the acetabular margin of the hip bone under cover of the gluteus minimus and joins the straight head at a right angle. The reflected head is blended with the capsular ligament of the hip joint. The heads after being united with each other form a fusiform belly which occupies the front of the thigh.

Insertion. In the lower one-third of the thigh the muscle ends in a flat tendon which descends vertically downwards and after receiving partial insertion from the vasti it is inserted into the upper part of the patella.

VASTUS LATERALIS. *Origin.* It arises (*i*) from the upper part of the trochanteric line, (*ii*) from the anterior and inferior aspects of the greater trochanter of the femur, (*iii*) from the lateral margin of the gluteal tuberosity, (*iv*) from the upper half of the lateral lip of the linea aspera and (*v*) from the lateral intermuscular septum.

It is inserted by a broad aponeurosis into the tendon of rectus femoris, the upper and the lateral borders of the patella and to the front of the lateral condyle of tibia by retinacular fibres which replace the anterolateral part of the capsule of the knee joint.

VASTUS MEDIALIS. *Origin.* It arises (*i*) from the lower part of the trochanteric line, (*ii*) from the spiral line of the femur, (*iii*) from the medial lip of the linea aspera, (*iv*) from the upper two-thirds of the medial supracondylar line, (*v*) from the tendon of the adductor magnus and (*vi*) from the medial intermuscular septum.

Insertion. It is inserted into the tendon of the rectus femoris, upper and to the medial margin of the petella and into the front of the medial condyle of the tibia by retinacular fibres which replace the anteromedial part of the capsule of the knee joint.

VASTUS INTERMEDIUS. *Origin.* It arises from the anterior and the lateral aspects of the upper three-fourths of the shaft of the femur and from the lower part of the lateral intermuscular septum.

Insertion. It is inserted into the deep surface of the tendons of the rectus femoris and the other vasti and is attached to the upper part of the patella.

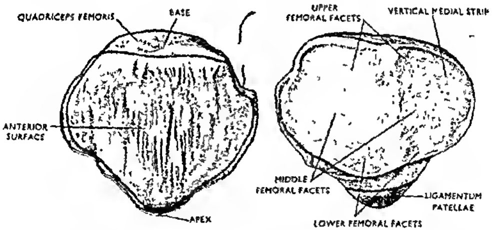


Fig. 555. The left patella; anterior and posterior aspects showing attachments.

The Common tendon of quadriceps femoris. The four parts of the quadriceps femoris end into a strong aponeurotic trilaminar tendon which converge to the patella, gain attachment into it, and finally is attached to the tubercle of the tibia as ligamentum patellae to gain its ultimate insertion.

The trilaminar tendon consists of fibres arranged in three layers or lamellae; the fibres from the rectus femoris are attached to the anterior part of the base of the patella and constitute the anterior lamella; those from the vastus intermedius are

attached to the posterior part of the base of the patella forming the posterior lamella; the intermediate lamella is formed by the fibres of the vastus lateralis and medialis and extends from the base of the corresponding side of the patella in a plane between the anterior and the posterior lamellae.

From the margins of the patella the aponeurotic fibres constitute the corresponding retinacular fibres which cover and replace the capsular ligament of the knee joint and gain attachment to the upper end of tibia as mentioned above.

Nerve supply. All the constituents of the quadriceps femoris are supplied by branches from the posterior division of the femoral nerve (L. 3 and 4). (The nerves supplying the three vasti also supply the knee joint and the nerve to the vastus intermedius in addition supplies the articularis genu; the nerve to rectus femoris also supplies a twig to the hip joint.)

Actions. The quadriceps femoris is the main *extensor of the knee joint* and thus adds to the propulsive force during running, walking, jumping etc. The rectus femoris in addition to extending the knee joint flexes the hip joint and this action is well manifested during kicking a football. It may be observed while kicking high a football that the hip is flexed with extension of the knee, and due to this action the rectus femoris is often referred to as a "kicking muscle". When the thigh is fixed the rectus femoris flexes the pelvis on the head of the femur. This action of rectus femoris is well marked while rising from recumbent to sitting posture.

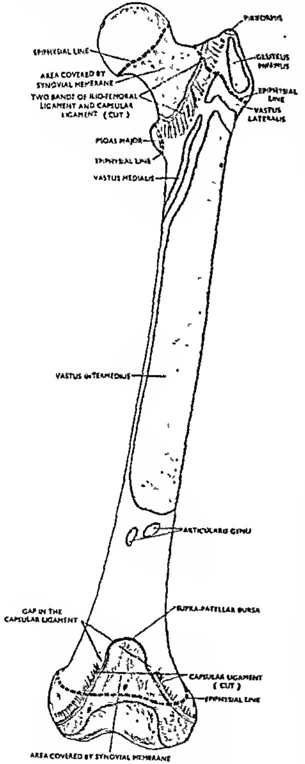


Fig. 556. The anterior view of left femur showing attachments.

Articularis Genu. It arises from the anterior surface of the lower part of the shaft of the femur under cover of the vastus intermedius and is inserted into the supra-patellar bursa.

Nerve supply. It is supplied by a branch from the nerve to the vastus intermedius.

Action. During extension of the knee joint it pulls the supra-patellar bursa upwards and thereby prevents it from being puckered during extension.

Sartorius. *Origin.* It is the largest muscle in the body and arises from the anterior-superior iliac spine and from the upper-half of the notch below it. From its origin it descends obliquely downwards and medially across the thigh from lateral to the medial side as a strap and forms the lateral wall of the femoral triangle and the roof of the adductor canal and finally passes behind the medial condyle of the femur to reach its insertion on the tibia.

Insertion. It ends in a flat tendon which is inserted into the upper part of the medial surface of the shaft of the tibia in front of the gracilis and the semitendinosus. Its tendon of insertion is separated from the tendons of gracilis and semitendinosus by a bursa and gives out two expansions, one anterior, blending with the capsular ligament of the knee joint, and the other posterior, blending with the deep fascia on the medial side of the leg.

Nerve supply. It is supplied by a branch from the anterior division of the femoral nerve through intermediate cutaneous nerve of the thigh (L. 2 and 3).

The sartorius muscle is pierced two nerves, the intermediate cutaneous nerve of the thigh and the infrapatellar branch of the saphenous nerve. The intermediate cutaneous nerve pierces it below its origin in the region of the femoral triangle while the infrapatellar branch of the saphenous nerve pierces it above its insertion on the medial side of the knee joint.

Action. It is the flexor of the knee joint and the abductor and the lateral rotator of hip joint. (It is the only muscle in front of the thigh that flexes the knee joint). Acting from below it flexes the pelvis on the same side and rotates it towards the opposite side.

Tensor fasciae latae. *Origin.* It arises from the anterior 5 cm. of the outer lip of the iliac crest, from the outer margin of the anterior superior iliac spine, from the outer margin of the notch below it and also from the deep surface of the fascia lata.

Insertion. It is inserted between the two layers of the ilio-tibial tract or band of the fascia lata opposite the junction of the middle and the upper-third of the thigh.

Nerve supply. It is supplied by a branch from the superior gluteal nerve (L. 4, 5 and S. 1).

Action. It tightens the fascia lata and the ilio-tibial tract and thereby helps in the extension of the knee joint.

MUSCLES ON THE MEDIAL ASPECT OF THE THIGH

The muscles on the medial aspect of the thigh are arranged into three strata—superficial, intermediate and deep. The muscles in the superficial stratum are, from medial to lateral side, the gracilis, adductor longus and the pectineus. Lying beneath the adductor longus and pectineus in the next (intermediate stratum) layer is the adductor brevis muscle while in the deep stratum is the adductor magnus. In between these three muscular layers there are two intermuscular spaces—one between the adductor longus and adductor brevis in which there lies the anterior branch of the obturator nerve, and another, between the adductor brevis and adductor magnus in which there lies the posterior division of the obturator nerve. Except the gracilis which is also a muscle of the knee joint all the other muscles in this region are the muscles of the hip joint.

Adductor longus. *Origin.* It is a triangular muscle and arises by a rounded small tendon from the anterior aspect of the body of the pubis immediately below the angle formed by the pubic crest and the superior ramus of the pubis.

Insertion. It soon forms a triangular muscular belly which descends downwards, backwards and laterally and is inserted by aponeurotic fibres into the middle-third of the linea aspera between the vastus medialis and the adductor magnus.

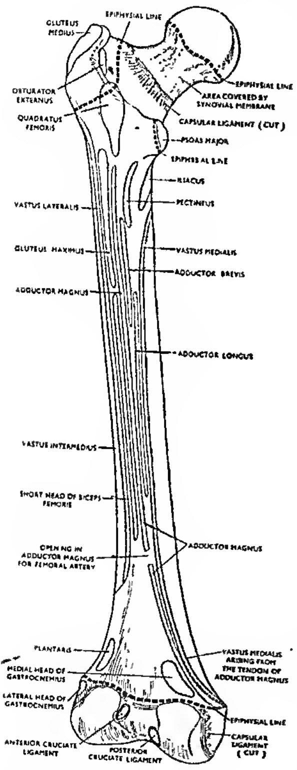


Fig. 557. The posterior view of left femur showing attachments.

Nerve supply. It is supplied by the anterior division of the obturator nerve (L. 2 and 3).

Actions. It is the adductor, flexor and lateral rotator of the hip joint. While in riding the action of adduction is best manifested when the saddle is grasped between the thighs.

Adductor magnus. It is a long triangular muscle which extends throughout the whole length of the thigh and occupies its postero-medial aspect. It is a composite muscle formed by fusion of an adductor mass and a hamstring mass and hence, the muscle has double nerve supply.

Origin. It arises from the lateral half of the lower triangular part of the ischial tuberosity, from the external surface of the ramus of the ischium and from external surface of the inferior ramus of the pubis.

Insertion. It is inserted into the femur as follows:

(1) Its pubic fibres pass horizontally lateralwards and are inserted into the medial margin of the gluteal tuberosity of the femur.

(2) The fibres from the ramus of the ischium descend obliquely downwards and laterally and end in an aponeurosis which is inserted into the linea aspera and into the upper part of the medial supracondylar line.

(3) The remaining fibres, that is, the fibres from the ischial tuberosity descend vertically downwards and form a rounded tendon which is inserted into the adductor tubercle on the medial condyle of the femur.

Relations. Anteriorly it is covered by the adductor longus, adductor brevis and sartorius. The ductor brevis intervenes between it and the adductor longus in the upper part of the thigh. The arteria profunda femoris at first is separated from it by the adductor brevis and then intervenes between it and the adductor longus. The femoral vessels lie in front of it opposite the sub-sartorial canal. Posteriorly it is covered by the hamstring muscle and is in relation with the sciatic nerve.

In the line of attachment of the adductor magnus to the femur there are five osseo-aponeurotic openings for the passage of blood vessels. The upper four openings are traversed by the four perforating branches of the arteria profunda femoris and the last one, which is the largest of all, is traversed by the femoral vessels and is situated at the line of fusion between the hamstring mass and the adductor mass at the junction of middle with the lower-third of the thigh. The upper border of the muscle runs horizontally lateralwards and ends in a free border which runs, edge to edge, with the lower border of quadratus femoris. The transverse branch of the medial circumflex femoral artery passes between the two muscles to join the cruciate anastomosis at the lower border of the greater trochanter of the femur. In erect posture its upper border, in its course lateralwards, crosses the lesser trochanter of the femur from which it is separated by a bursa.

Nerve supply. Its adductor part is supplied by the posterior division of the obturator nerve (L. 2 and 3) and its hamstring part by a branch from the medial popliteal division of the sciatic nerve (L. 3, 4 and 5).

Action. Its adductor part is a strong adductor, a weak flexor and a lateral rotator of the thigh in the hip joint; its hamstring part is an extensor and a medial rotator of the thigh in the hip joint.

Comparative Anatomy. In many lower vertebrates the hamstring portion of the adductor magnus, that is, the fibres that arise from the ischial tuberosity, is inserted into the tibia and is known as "presemimembranosus". In man the medial ligament of the knee joint represents its degenerated distal attachment to the tibia.

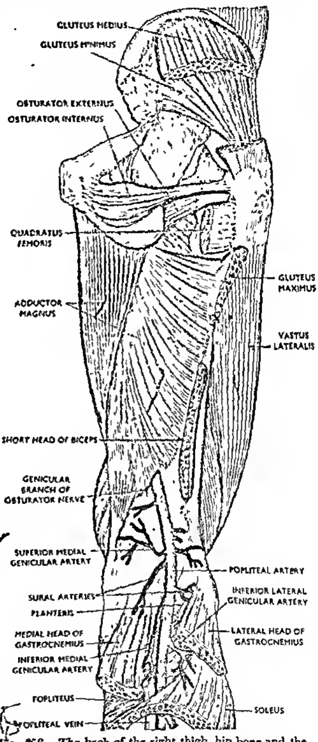


Fig. 358. The back of the right thigh, hip bone and the upper leg. Note the disposition of the muscles and the popliteal artery with its branches.

Adductor brevis. It is the smallest of the adductor muscles, triangular in shape and lies beneath the adductor longus and the pectineus.

Origin. It arises from the femoral surface of the body and the inferior ramus of the pubis between the gracilis and the obturator externus.

Insertion. It becomes aponeurotic and is inserted into the femur along the line leading from the lesser trochanter to the upper part of the linea aspera immediately behind the pectineus.

Nerve supply. It is supplied by the anterior division of the obturator nerve (L. 2, 3 and 4).

Action. Same as adductor longus.

Gracilis. It is a long ribbon-like flat muscle which descends vertically downwards on the most medial aspect of the thigh and is the most superficial one amongst the adductor members of the thigh.

Origin. It arises from the anterior aspect of the body and the inferior ramus of the pubis and from the anterior aspect of the ramus of the ischium. It forms ribbon-like muscular belly which descends vertically downwards, and before its termination, it passes behind the medial condyle of the femur and tibia.

Insertion. It is inserted into the upper part of the medial surface of the tibia behind the sartorius and above the semitendinosus muscle.

Nerve supply. It is supplied by the anterior division of the obturator nerve (L. 2, 3 and 4).

Action. It is the adductor, flexor and medial rotator of the hip joint. It is also a weak flexor of the knee joint.

Pectineus. It is a quadrilateral-shaped muscle situated in the floor of the femoral triangle in between the psoas tendon and the adductor longus muscle.

Origin. It airses from the pectineal line and from the adjoining pectineal surface of the superior ramus of the pubis.

Insertion. It descends downwards, backwards and laterally and is inserted into a line descending downwards from the lower part of the lesser trochanter to the linea aspera of the femur.

Actions. It is the flexor and adductor of the hip joint and also rotates the thigh lateralward.

Nerve supply. It is supplied by the nerve to the pectineus from the femoral nerve (L. 2 and 3), by the anterior branch of the obturator nerve (L. 2 and 3) and by the accessory obturator nerve when it exists. Its double nerve supply indicates its foetal origin from both the compartments of the thigh, flexor and extensor.

THE MUSCLES AND FASCIA OF THE GLUTEAL REGION

DEEP FASCIA. The deep fascia of the gluteal region is the upward continuation of the fascia lata. *Above* it is attached to the iliac crest and *posteriorly* to the sacrum and coccyx. *Anteriorly* it is thick and membranous and covers the anterior part of the gluteus medius muscle; reaching the upper border of the gluteus maximus it splits into two lamellae which enclose the gluteus maximus muscle and then reaching its lower border reunite to form a single layer which is continuous with the deep fascia of the thigh.

The contrasting feature of the fascia is that, anteriorly, where it covers the gluteus medius, it is very strong and membranous but where it covers the gluteus maximus it is thin and delicate.

Gluteus maximus. It is the most superficial of the gluteal muscles and is a quadrilateral-shaped large muscle which is responsible for the *prominence of the buttock.* The gluteal prominence is a human characteristic and is due to the erect posture assumed by man.

Origin. It arises (i) from the lateral surface of the ilium between the posterior-fifth of the iliac crest and the posterior gluteal line, (ii) from the sides of the last two segments of the sacrum and the first three segments of the coccyx, (iii) from the

posterior surface of the sacrotuberous ligament, (*iv*) from the posterior layer of the gluteal aponeurosis and (*v*) from the fascia covering the sacrospinalis muscle.

Insertion. It consists of superficial and deep fibres. All the superficial fibres are inserted into the iliotibial tract while the deep fibres of the upper-half similarly pass to the iliotibial tract. The deep fibres of the lower-half are inserted to the gluteal tuberosity on the back of the femur.

Nerve supply. It is supplied by the inferior gluteal nerve (L. 5 and S. 1, 2).

Action. Acting from above it is the extensor and lateral rotator of the hip joint, tensor of the fascia lata and also a weak extensor of the knee joint through the iliotibial tract. It also adducts the thigh during extension and abducts it during flexion. It is also a powerful anti-gravity muscle. Acting from below it extends the trunk on the femur as in getting up from stooping to erect posture.

The movement of extension by gluteus maximus is associated with extremes of movement of the hip joint as in running, jumping, and in rising the stairs. During ordinary walking its activity as an extensor is very little or it fails to become active. It appears that during extremes of movement the muscle gets a better leverage to work than in ordinary movement.

STRUCTURE LYING DEEP TO GLUTEUS MAXIMUS:

A. *Bones:*
- (*a*) Ischial tuberosity.
- (*b*) Greater trochanter of the femur.

B. *Bursa:*
- (*a*) Over the tuber ischii.
- (*b*) Between the gluteus maximus and the vastus lateralis.
- (*c*) Between the greater trochanter and the iliotibial tract.

C. *Muscles:*
- (*a*) Gluteus medius.
- (*b*) Piriformis.
- (*c*) Gemellus superior, gemellus inferior and the tendon of obturator internus.
- (*d*) Tendon of obturator externus.
- (*e*) Quadratus femoris.
- (*f*) Adductor magnus.
- (*g*) Origin of biceps femoris, semimembranosus and semitendinosus (Hamstring muscles).
- (*h*) Part of origin of the vastus lateralis.

D. *Ligaments*: Sacrotuberous and sacrospinous ligaments.

E. *Blood vessels:*
- (*a*) Superior gluteal.
- (*b*) Inferior gluteal.
- (*c*) Internal pudendal.
- (*d*) Ascending and transverse branches of medial circumflex femoral artery.
- (*e*) First perforating branch of the arteria profunda femoris.

F. *Nerves:*
- (*a*) Superior gluteal.
- (*b*) Inferior gluteal.
- (*c*) Sciatic.
- (*d*) Pudendal.
- (*e*) Posterior femoral cutaneous nerve.
- (*f*) Nerve to the obturator internus.
- (*g*) Nerve to the quadratus femoris.

Dispositions of the muscles under cover of the gluteus maximus. As soon as the gluteus maximus is reflected the following muscles will be noticed from above downwards:

(1) Gluteus medius. It lies partly under cover of and partly above and in front of the upper border of the gluteus maximus.
(2) Piriformis.
(3) Gemellus superior.
(4) Obturator internus.

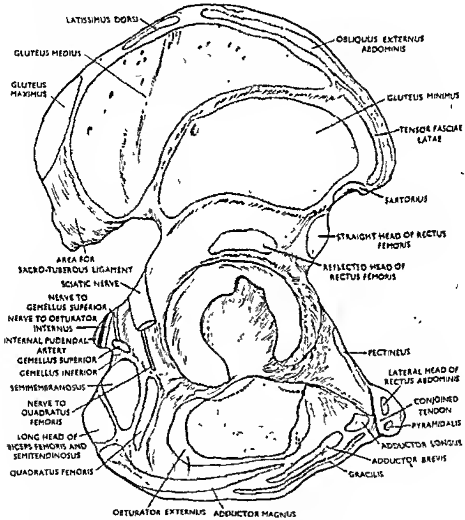


Fig. 559. The external view of the right hip bone to show the muscular attachments with some of the relations.

(5) Gemellus inferior.
(6) Quadratus femoris.
(7) Upper portion of the adductor magnus.

Deep to the quadratus femoris and the upper part of the adductor magnus and arising from the ischial tuberosity from lateral to medial side are the following:

(8) Biceps femoris.
(9) Semitendinosus.
(10) Ischial portion of the adductor magnus.

Under cover of the gluteus medius there lies the gluteus minimus; under cover of the quadratus femoris is the tendon of the obturator externus and under cover of

and in between the common tendon of semitendinosus and long head of the biceps femoris is the semimembranosus. The gluteus minimus hides the tendon of origin of the reflected head of the rectus femoris muscle.

Gluteus minimus muscle. *Origin and insertion.* It is a triangular muscle which lies under cover of the gluteus medius and is the smallest of the three glutei muscles. It arises from the external surface of the ilium between the middle and inferior gluteal lines and is inserted into the anterior surface of the greater trochanter. The muscle is intimately connected at its insertion with the capsule of the hip joint.

Nerve supply. It is supplied by the superior gluteal nerve (L. 4, 5 and S. 1).

Actions. Acting from above it is the abductor of the hip joint. It also rotates the thigh medially during flexion and rotates it laterally during extension. Acting from below, that is, when the femur is fixed it tilts the pelvis laterally as in standing on one leg, and thus acting from opposite side, it prevents sagging down of the pelvis on the unsupported side when the leg is off the ground. This is one of the most important action of both gluteus medius and minimus and is called into play during walking, when during propulsion, one leg is to carry the weight of the body.

Relation. Superficially the gluteus minimus is overlapped by the gluteus medius muscle and between this muscle and the gluteus medius are the superior gluteal vessels and the superior gluteal nerve. Deep to the gluteus minimus muscle are the reflected tendon of the rectus femoris and the capsule of the hip joint.

Gluteus medius. It is a triangular muscle which lies partly under cover of the gluteus maximus; its anterior part is superficial being covered only by the skin superficial and the deep fasciae.

Origin. It arises from the outer surface of the ilium between the posterior gluteal line and the iliac crest above and the middle gluteal line below; and some of its fibres also arise from the strong fascia that covers this muscle.

Insertion. The fibres converge to a flat tendon which is inserted into the oblique ridge on the lateral surface of the greater trochanter of the femur.

Nerve supply. It is supplied by the superior gluteal nerve (L. 4, 5 and S. 1).

Action. Acting from the pelvis the gluteus medius abducts the thigh and rotates it medially. Acting from the femur it causes slight rotation of the pelvis and keeps the transverse axis of the pelvis in horizontal position when the opposite limb is off the ground as in walking and running.

Obturator externus. It is a triangular muscle which lies under cover of the quadratus femoris muscle and passes backwards and laterally from its origin to its insertion.

Origin. . It arises from the lateral aspect of the anterior two-thirds of the obturator membrane, from the lateral surface of the rami of the pubis and ischium and from the obturator surface of the superior ramus of the pubis.

Insertion. The muscle ends in a tendon which passes through a groove between the acetabulum and the tuberosity of the ischium and is inserted into the trochanteric fossa of the femur.

In its course it passes backwards and laterally beneath the neck of the femur to gain its posterior aspect where it usually produces an impression. A bursa may be interposed between the tendon and the bone.

Nerve supply. It is supplied by the posterior division of the obturator nerve (L. 3 and 4).

Actions. It is the lateral rotator of the thigh and stabilises the proximal part of the femur.

Obturator internus. It arises from within the pelvic cavity and comes out from the same through the lesser sciatic foramen and closes the obturator foramen from the internal aspect.

Origin. Its fibres take origin from the pelvic surface of the rami of the ischium and pubis, obturator membrane, body of the pubis and from the lower pelvic surface of the ilium.

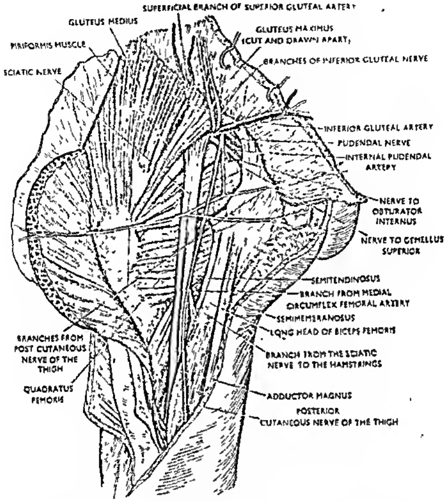


Fig. 560. The structures under the gluteus maximus. From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

Insertion. It ends in a tendon which makes a right-angled bend to wind round the lesser sciatic foramen where it unites with the gemellus superior et inferior and forms a common tendon of insertion which passes through the groove above the ischial tuberosity. Then it is inserted into the medial surface of the greater trochanter of the femur above and in front of the trochanteric fossa. In its course the tendon crosses the posterior part of the capsular ligament.

Nerve supply. It is supplied by the nerve to the obturator internus (L. 5 and S. 1, 2).

Actions. Together with the gemellus superior et inferior it rotates the thigh laterally.

Gemellus superior. It arises from the outer surface and the lower border of the ischial spine and soon joins with the obturator internus tendon and is inserted into the medial surface of the greater trochanter above and in front of the trochanteric fossa.

Nerve supply. It is supplied by the nerve to the obturator internus (L. 4, 5 and S. 1).

Actions. Same as obturator internus.

Gemellus inferior. It arises from the upper part of the ischial tuberosity immediately above the groove for the obturator internus and soon joins the latter muscle and through its tendon it receives its insertion.

Nerve supply. It is supplied by the nerve to the quadratus femoris (L. 4, 5 and S. 1).

Action. Same as obturator internus.

Quadratus femoris. It is a quadrilateral-shaped muscle and covers the obturator externus tendon. It arises from the anterior surface of the body of the ischium in front of the ischial tuberosity and is inserted into the quadrate tubercle on the trochanteric crest of the femur.

Nerve supply. It is supplied by the nerve to the quadratus femoris (L. 4, 5 and S. 1).

Actions. It rotates the thigh laterally.

Piriformis. It arises from the margins of the anterior sacral foramina of the sacrum, from the bar of bone that separates the anterior sacral foramina, from the upper border of the greater sciatic notch and from the upper surface of the sacrotuberous ligament. It comes out of the pelvis through the greater sciatic foramen and is inserted by a tendon into a depression on the upper border of the greater trochanter of the femur.

Nerve supply. It is supplied by branches from the first and second sacral nerves.

Action. It rotates the thigh laterally.

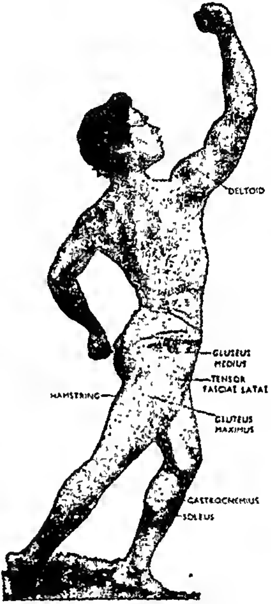


Fig. 561. Some of the muscles are in active contraction (seen from the right side). With the kind courtesy of "Biswa Sree" Monotosh Roy.

Functional classifications of the muscles around the hip joint:

(A) **Flexors of the hip joint:**

(1) Iliacus (2) Psoas	Prime mover.
(3) Pectineus (4) Rectus femoris (5) Sartorius (6) Adductors	Synergists.

(B) Extensors of the hip joint:

(1) Gluteus maximus—Prime mover.
(2) Hamstrings—Synergists.

(C) Abductors of the hip joint:

(1) Gluteus medius
(2) Gluteus minimus } Prime mover.
(3) Tensor fasciae latae
(4) Sartorius—Synergist.

(D) Adductors of the hip joint:

(1) Adductor longus
(2) Adductor brevis } Prime mover.
(3) Adductor magnus

(4) Pectineus
(5) Gracilis } Synergists.

(E) Medial rotators of the hip joint:

(1) Tensor fasciae latae.
(2) Gluteus minimus et medius.

(F) Lateral rotators of the hip joint:

(1) Obturator internus et externus
(2) Gemellus superior et inferior } Prime mover.
(3) Quadratus femoris
(4) Piriformis, gluteus maximus, sartorius and the adductors—Synergists.

BACK OF THE THIGH

Hamstrings. *The biceps femoris, semimembranosus and semitendinosus* muscles are collectively called the hamstring muscles. They form the principal muscles on the back of the thigh, and opposite the lower-third of the thigh, they form two diverging groups of muscles, of which, the semimembranosus and semitendinosus pass to the medial side of the knee joint and biceps femoris passes to the lateral side of the knee joint and they form the medial and lateral hamstrings respectively. As they diverge they form the popliteal fossa.

Each hamstring muscle bears the following common characteristics:

(1) Each arises from the ischial tuberosity.
(2) It is inserted into one or the other of the two bones of the leg.
(3) It is supplied by the medial or tibial division of the sciatic nerve.

Considering the above facts the portion of the adductor magnus arising from the ischial tuberosity may be taken into account as one of the hamstring muscles and thus constituting the fourth muscle of the hamstring group.

The reason for this is that it arises from the ischial tuberosity, it is supplied by the medial division of the sciatic nerve and in embryonic life it gained its insertion into the tibia through the medial ligament of the knee joint which ~~is the~~ fibrous remains of the embryonic insertion of the adductor magnus. Similarly the short head of the biceps femoris cannot be counted as a member of the hamstrings because it arises from the linea aspera instead of from the ischial tuberosity and it is enervated through the lateral division of the sciatic nerve.

Biceps femoris. It arises by two heads—long and short.

The long head arises from the lower and medial part of the ischial tuberosity in common with the semitendinosus and also from the adjoining part of the sacro-

tuberous ligament. It descends obliquely downwards from medial to lateral side crossing the sciatic nerve in its course and opposite the lower-third of the thigh it joins its short head. The *short head arises* from the linea aspera, from the upper part of the lateral supracondylar line and from the lateral intermuscular septum.

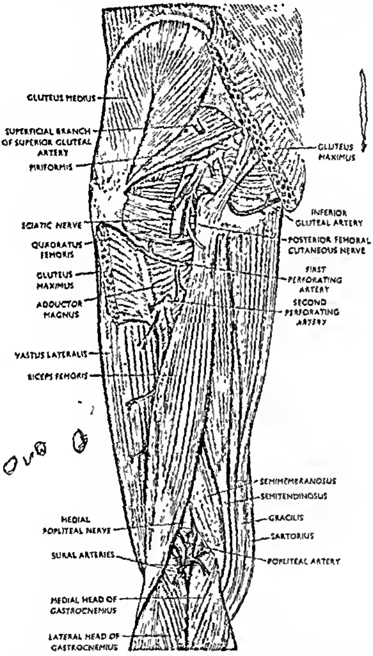


Fig. 562. The back of the right thigh and hip after partial removal of the gluteus maximus. *From the dissection hall, N. R. Sircar Medical College, Cal; with the kind* permission from the Prof. of Anatomy.

It joins the long head and forms a tendon which splits into two limbs to embrace the lateral ligament of the knee joint and is finally inserted into the upper and lateral part of the head of the fibula. Some of its fibres may extend into the adjoining portion of the lateral condyle of the tibia.

Actions. It flexes the knee joint and rotates it medially.

N.B. The hamstring muscles acting together flex the knee joint and extend the hip joint and consequently when the thigh is fully flexed on the abdomen full extension of the knee joint is impossible.

Hybrid or composite muscles. The muscles that are supplied by two or more nerves of different origin have usually more than one component parts during morphological life, which in later life are amalgamated to form a single muscle and are known as *hybrid or composite muscles*. The adductor magnus, which is a composite muscle, consists of two distinct muscles in early embryonic life and they occupy the morphological front aspect of the thigh. The obturator nerve and the medial division of the sciatic are the nerves of the morphological front and the two different portions of the adductor magnus receive their nerve supply from these two different nerves. During later period of embryonic life the two parts of the adductor magnus are amalgamated to form a single muscle and due to rotation of the limb it comes to occupy the back of the thigh. And this explains the source of its double nerve supply. The biceps femoris is also a composite muscle and in morphological life the two different heads of the biceps constitute two different muscles of which the long head lies in the morphological front region and is supplied by the medial division of the sciatic nerve which is a nerve of the morphological front, and the short head lies in the morphological back region and is supplied by the lateral division of the sciatic nerve which is a nerve of the morphological back. Pectineus is also an example of the composite muscle and has double nerve supply (femoral and the obturator nerve).

N.B. The femoral nerve and the lateral division of the sciatic nerve are the nerves of the morphological back while the obturator nerve and the medial division of the sciatic nerve are the nerves of the morphological front. Due to rotation, the muscles that we find in the anterior or front region during early embryonic life, becomes the back muscles during later life and so is the case with the nerves.

NEUROLOGICAL VALUE OF THE MUSCLES OF THE THIGH AND GLUTEAL REGIONS:

Muscles supplied by the obturator nerve (L. 2, 3 and 4):

(1) Gracilis (L. 2, 3 and 4).
(2) Adductor longus (L. 2 and 3).
(3) Pectineus (L. 2, 3 and 4).
} Through its anterior branch.

(4) Obturator externus (L. 3 and 4).
(5) Adductor brevis (L. 2, 3 and 4).
(6) *Adductor magnus* (L. 3 and 4).
} Through its posterior branch.

Muscles supplied by the femoral nerve:

(1) Pectineus.
(2) Sartorius (L. 2 and 3 through anterior divisions).
(3) Quadriceps femoris (L. 2, 3 and 4 through posterior branches).
  (*a*) Rectus femoris.
  (*b*) Vastus lateralis.
  (*c*) Vastus medialis.
  (*d*) Vastus intermedius.
(4) Articularis genu (through the nerve to the vastus intermedius).

Muscles supplied by the superior gluteal nerve:

(1) Gluteus medius (L. 4, 5 and S. 1).
(2) Gluteus minimus (L. 4, 5 and S. 1).
(3) Tensor fasciae latae (L. 4, 5 and S. 1).

Muscles supplied by the inferior gluteal nerve:

(1) Gluteus maximus (L. 5 and S. 1, 2).

Muscles supplied by the nerve to the obturator internus:

(1) Obturator internus (L. 5 and S. 1, 2).
(2) Gemellus superior (L. 5 and S. 1, 2).

Muscles supplied by the nerve to the quadratus femoris:

(1) Quadratus femoris (L. 4, 5 and S. 1).
(2) Gemellus inferior (L. 4, 5 and S. 1, 2).

Muscles supplied by the sciatic nerve:

By medial popliteal division:

(1) Long head of biceps femoris (S. 1, 2 and 3).
(2) Ischial fibres of adductor magnus (L. 4 and 5).
(3) Semimembranosus (L. 4, 5 and S. 1).
(4) Semitendinosus (L. 4, 5 and S. 1, 2).

By lateral popliteal division:

(1) Short head of biceps femoris (L. 5 and S. 1).

2/3

POPLITEAL FOSSA

It is a diamond-shaped space situated behind the knee joint and extends above to the lower-third of the thigh and below to the upper-fourth of the leg. As it is diamond-shaped, the space is widest opposite its centre and narrow both above and below. It has a roof, a floor, a lateral wall and a medial wall. The fossa can be exposed by three incisions—one transverse incision across the back of the thigh opposite the junction of the middle with the lower-third of the thigh, another transverse incision opposite the junction of the upper with the lower three-fourths of the back of the leg. The third is a vertical incision joining the mid-points of the two former incisions. The skin and the subcutaneous tissue are to be reflected on either side.

The *roof* or the *posterior wall* is formed by the popliteal fascia (deep fascia) and the skin and the superficial fascia. The short saphenous vein which ascends upwards and lies in the superficial fascia pierces the roof of the popliteal fossa opposite the back of the knee joint. The terminal portion of the posterior cutaneous nerve of the thigh pierces the roof to become subcutaneous and descends along with the terminal portion of the short saphenous vein as far as the middle of the back of the leg.

The *floor* is formed by the popliteal surface of the femur, posterior oblique ligament of the knee joint, popliteus and its covering fascia.

The *lateral wall* is formed above by the biceps femoris and below by the plantaris and the lateral head of the gastrocnemius.

The *medial wall* is formed above by the semimembranosus and the semitendinosus and below by the medial head of the gastrocnemius.

Contents. The contents of the popliteal fossa are the popliteal artery with its branches, popliteal vein and its tributaries, the medial and the lateral popliteal nerves with their branches, the articular branch of the posterior division of the obturator nerve, popliteal lymph gland and a quantity of fat.

Popliteus. It has a tendinous origin and arises from the anterior part of the groove on the lateral aspect of the lateral condyle of the femur. Its tendon of origin lies within the capsular attachment and after piercing the same it comes out of it and forms a triangular muscular belly which curves backwards, downwards and medially to be inserted into the upper two-thirds of the triangular area above the soleal line on the back of the tibia.

Nerve supply. It is supplied by the nerve to the popliteus (L. 4, 5 and S. 1), a branch of the medial popliteal nerve and crossing superficial to the distal portion of the popliteal artery and the popliteus muscle it hooks round its lower border and then enters into its deep surface.

Actions. It first flexes the knee joint and rotates it medially. When the knee joint is fully extended the joint is locked between the two cruciate ligaments and the [pop]liteus by having its advantageous position breaks this locking mechanism and ini-

plantar-flexion which is subsequently carried out by the assistance of other flexor muscles. Due to the reasons that it unlocks the joint it is sometimes called the "unlocking muscle" of the knee joint.

THE LEG

Fascia cruris. The fascia cruris or the deep fascia of the leg invests the muscles around the leg and is continuous above with the fascia lata and below with the fascia around the ankle joint.

Attachment. Above and in front, it is attached to the margins of the *patella*, ligamentum patellae and the tuberosity of the tibia. Above and laterally, it is attached to the lateral condyle of the tibia and to the head of the fibula. Above and medially it is attached to the medial condyle of the tibia. Above and posteriorly, it does not receive any bony attachments but is continuous with the popliteal fascia covering the popliteal fossa which is continuous with the fascia lata. In this situation it is strengthened laterally by an expansion from the tendon of the biceps femoris and medially by an expansion from the tendon of the sartorius, gracilis, semitendinosus and semimembranosus.

Below it is attached to the bony prominences around the ankle joint and is continuous with the flexor and extensor retinacula.

Distribution and features. It surrounds the leg like a sock and invests the muscles of the leg. In its course of distribution it is attached to the medial margin, medial surface and the anterior margin of the tibia. While investing the muscles it sends out three intermuscular septa—two vertical, anterior and posterior, and one transverse. The *anterior intermuscular septum* intervenes between the extensors and the peroneal muscles and is attached to the anterior border of the fibula. The *posterior intermuscular septum* intervenes between the peroneal and the flexor muscles and is attached to the posterior border of the fibula. The transverse septum known as the *transverse fascia* of the leg intervenes between the superficial and the deep group of flexor muscles. Besides these different septa it sends out processes which enclose individual muscle.

The fascia cruris is not uniform in its texture and it is thick and dense anteriorly and above and gives origin to tibialis anterior and extensor digitorum longus from its deep surface. It is very thin posteriorly where it covers the gastrocnemius and the soleus.

Tibialis anterior. It lies against the lateral surface of the shaft of the tibia and forms a fleshy belly above, which ends in a flat tendon opposite the lower-third of the leg. It arises from the upper two-thirds of the lateral surface of the body of the tibia, from the anterior surface of the interosseous membrane, from the intermuscular septum between it and the extensor digitorum longus and from the deep surface of the fascia cruris. Its fibres run vertically downwards and end in a flat tendon opposite the lower-third of the leg. Its tendon passes behind the superior and inferior extensor retinacula and then curves medially to reach the medial margin of the foot where it is inserted into the infero-medial aspect of the medial cuneiform bone and the base of the first metatarsal bone.

Nerve supply. It is supplied by the anterior tibial nerve (L. 4, 5 and S. 1).

Actions. It dorsiflexes the ankle joint and inverts the foot, that is, it raises the medial margin of the foot.

Extensor digitorum longus. It arises from the upper three-fourths of the anterior surface of the shaft of the fibula, from the lateral condyle of the tibia, from the anterior aspect of the interosseous membrane, from the deep surface of the fascia cruris, and from the crural intermuscular septum and the septum between it and the tibialis anterior muscle. The muscular belly soon divides into four tendons which pass beneath the superior and the inferior extensor retinacula along with the peroneus tertius and then the tendons diverge from one another

pass forwards to be inserted into the second, third, fourth and the fifth toes in the following manner: Opposite the metatarso-phalangeal joint each of the tendon for the second, third and the fourth toes is joined on its lateral side by the tendon of the extensor digitorum brevis and also receives fibrous expansions from the lumbricales and the interossei muscles and forms an expanded tendon which covers the dorsum of the proximal phalanx (extensor expansions) and divides into three slips—one intermediate and two collateral. The intermediate slip is inserted into the dorsal aspect of the middle phalanx of the second row. The two collateral slips unite together and are inserted into the dorsal aspect of the distal phalanx. That for the fifth toe is not joined by the tendon of the extensor digitorum brevis muscle and is joined on its medial side by the expansions from the third plantar interosseous muscle and the fourth lumbricalis muscle and then is inserted as above.

Nerve supply. It is supplied by the anterior tibial nerve (L. 4, 5 and S. 1).

Actions. It dorsiflexes the phalanges of the lateral four toes and in continued action dorsiflexes the ankle joint.

Peroneus tertius. It arises from the lower one-third of the anterior surface of the shaft of the fibula, from the anterior surface of the lower part of the interosseous membrane and from the crural intermuscular septum. It forms a tendon which passes beneath the superior and the inferior extensor retinacula along with the extensor digitorum longus and then passes laterally to receive its insertion on the medial aspect of the dorsum of the base of the fifth metatarsal bone.

Nerve supply. It is supplied by the anterior tibial nerve (L. 4, 5 and S. 1).

Actions. It is the dorsiflexor of the ankle joint and everts the lateral margin of the foot.

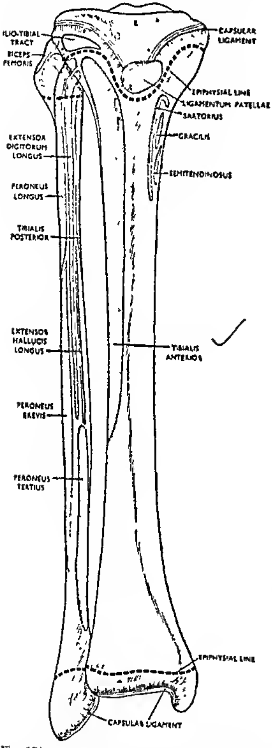


Fig. 564. The front view of the bones of the right leg to show muscular attachments.

Extensor hallucis longus. It lies between the tibialis anterior and the extensor digitorum longus and arises from

the middle two-fourths of the anterior surface of the fibula and from the middle two-fourths of the anterior surface of the interosseous membrane. It ends in a tendon which passes deep to the superior and inferior extensor retinacula and passes to the great toe where it is inserted into the dorsal aspect of the distal phalanx.

Nerve supply. It is supplied by the anterior tibial nerve (L. 4, 5 and S. 1).

Actions. It extends the phalanges of the great toe and in continued action dorsiflexes the ankle joint.

The crural interosseous membrane. The crural interosseous membrane connects the tibia and the fibula opposite their interosseous borders and separates the muscles of the front of the leg from the muscles of the back.

Attachment. It is attached to the interosseous border of the tibia and commences from below the fibular facet on the tibia to the point where the interosseous border bifurcates and is then continuous with the inferior interosseous tibio-fibular ligament which is attached to the rough triangular area enclosed by the limbs of the bifurcated interosseous border. Its fibres are directed downwards and laterally and are attached to the corresponding border of the fibula.

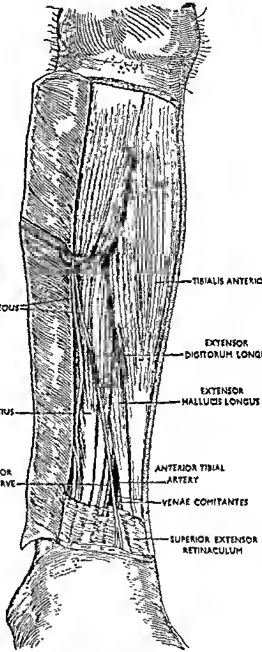


Fig. 565. The right tibio-fibular region to show the structures in the extensor compartment.

From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

Relations. Anterior surface. The anterior surface is in relation to the tibialis anterior, extensor digitorum longus, extensor hallucis longus, the peroneus tertius muscles and the anterior tibial vessels and nerve. Opposite the neck of the fibula it is pierced by the anterior tibial vessels, and above the ankle joint, it is pierced by the perforating branch of the peroneal artery.

Posterior surface. The posterior surface is in relation to the tibialis posterior and the flexor hallucis longus.

Functions. Same as that of the interosseous membrane of the forearm.

N.B. Above the opening of the anterior tibial vessels, the fibres of the crural interosseous membrane are directed downwards and medially but below this opening its fibres are directed downwards and laterally.

Extensor tendons:

(a) The *tendon* of the *tibialis anterior* is the medialmost tendon on the dorsum of the foot and passes to the medial *margin of the foot where it is inserted into antero-*medial aspect of the medial cuneiform bone and into the medial side of the base of the first metatarsal bone.

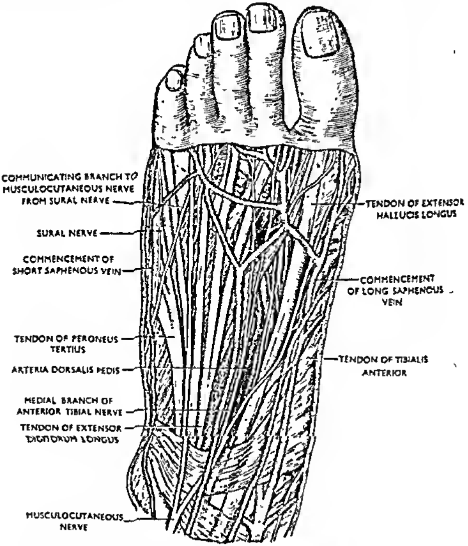


Fig. 566 The dorsum of the right foot. From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

(b) The tendon of the extensor hallucis longus lies on the lateral side of the tibialis anterior tendon and occupies the dorsum of the first metatarsal bone and the dorsum of the great toe and finally is inserted into dorsal aspect of the base of the distal phalanx of the great toe. Opposite the root of the great toe it is joined on its lateral side by the first tendon of the extensor digitorum brevis.

(*c*) *Extensor digitorum longus.* It consists of four tendons, each passing to the second, third, fourth and the fifth toe and is inserted into the dorsal aspect of the distal phalanx of the corresponding toe. The tendons for the second, third and the fourth toes are accompanied by the tendon of the extensor digitorum brevis.

(*d*) *Peroneus tertius tendon.* Its tendon lies on the lateral side of the extensor digitorum longus tendon and passes to the lateral margin of the foot to be inserted into the dorsal aspect of the base of the fifth metatarsal bone medial to the peroneus brevis tendon.

Extensor digitorum brevis. It lies under cover of the extensor digitorum longus tendons and forms a short muscular belly which arises from the anterior part of the superior surface of the calcaneus and passes obliquely forwards and medially and then divides into four tendons. The first tendon crosses the terminal portion of the arteria dorsalis pedis and this is inserted along with the extensor hallucis longus tendon, the remaining three tendons are inserted along with the extensor digitorum longus tendons.

Dorsal interosseous muscle. When the extensor tendons are reflected to one side portions of the four dorsal interosseous muscles are exposed and occupy the intermetatarsal spaces.

Superior extensor retinaculum. It is the localised thickening of the deep fascia of the leg situated in front of the ankle joint and is attached laterally to the anterior margin of the triangular subcutaneous area on the lateral surface of the lower end of the fibula and medially to the medial malleolus of the tibia. The extensor tendons and the anterior tibial vessels and nerves pass deep to it to reach the dorsum of the foot. The musculocutaneous nerve crosses superficial to it laterally whereas the long saphenous vein and the saphenous nerve cross it medially.

Inferior extensor retinaculum. It is a 'Y'-shaped ligament situated below the superior extensor retinaculum and consists of a stem and two limbs. The stem is attached to the anterior part of the superior surface of the calcaneum; the superior limb is attached to the medial melleolus whereas the inferior limb passes across the medial margin of the foot to become continuous with the plantar aponeurosis.

Inferior peroneal retinaculum. It is situated at the antero-inferior part of the lateral malleolus and is attached above to the anterior part of the superior surface of the calcaneum where it is continuous with the stem of the inferior extensor retinaculum and is attached below to the peroneal tubercle on the lateral surface of the calcaneum. It fixes the peroneus longus et brevis tendons together.

Peroneus longus et brevis tendons. They lie beneath the inferior peroneal retinaculum, the brevis being situated in front of the longus. The peroneus brevis is inserted into the dorsal aspect of the base of the fifth metatarsal bone lateral to the peroneus tertius. The peroneus longus tendon passes to the sole of the foot.

Gastrocnemius. *Origin.* It arises by two tendinous heads—lateral and medial from the condyles of the femur. The lateral head takes its origin from an impression on the lateral surface of lateral condyle, from the adjacent lateral supracondylar line of the femur and from the capsular ligament of the knee joint. The medial head, the larger of the two, arises from a depression at the upper and posterior part of the medial condyle above the adductor tubercle, from the rough area on the popliteal surface of the femur medially and from the adjoining capsular ligament.

Insertion. The two heads soon come in close contact with each other and spread out into two rounded bellies which remain separated from each other and are inserted into a broad aponeurosis which is gradually contracted and receives the insertion of the soleus to form the tendo-calcaneus which is inserted into the middle compartment of the posterior surface of the cancaneum.

Nerve supply. It is supplied by the medial popliteal nerve.

Soleus. *Origin.* It lies in front of the gastrocnemius muscle and

the back of the head of the fibula, from the upper one-fourth of the posterior surface of the shaft of the fibula, from the soleal line of the tibia, from the middle one-third of the medial border of the tibia and from the deep transverse fascia of the leg.

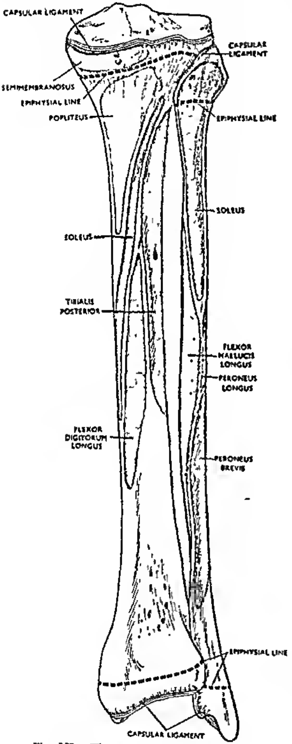


Fig. 567. The back view of the bones of the right leg with muscular attachments.

Insertion. The muscular belly soon unites with the aponeurosis of the gastrocnemius to form the tendocalcaneus and is inserted into the middle compartment of the posterior surface of the calcaneum.

Nerve supply. It is supplied by the medial popliteal nerve (S. 1 and 2) and by the posterior tibial nerve (L. 5 and S. 1).

Action. Both the gastrocnemius and the soleus are the chief plantar flexors of the ankle joint.

The tendocalcaneus. It is the common tendon of insertion of gastrocnemius and soleus and is the strongest tendon in the body. It is about 6 inches long and gradually narrows to a point about $1\frac{1}{2}$ inches above the calcaneum and then is expanded and finally is inserted into the middle of the posterior surface of the calcaneum.

N. B. The muscular bellies of the gastrocnemius and soleus constitute the main bulk of the calf muscle and are responsible for the rounded muscular prominence on the back of the leg. They are stronger and bulkier than the extensor muscles because during walking or running they are to raise the body weight from the ground. Sometimes they are described as the triceps muscle of the leg or triceps sura.

Plantaris. It forms a very long tendon and has a small fusiform muscular belly. It rises from the lower part of the lateral supracondylar line, from the adjoining portion of the lateral part of the popliteal surface of the femur and from the oblique posterior ligament of the knee joint. It forms a small fusiform belly which soon ends in a tendon which passes obliquely from lateral to the medial side between the gastrocnemius and the soleus and then follows the medial margin

the tendocalcaneus and finally is inserted into the medial margin of the intermediate area on the posterior surface of the calcaneum. It may end by being inserted either in the deep fascia or in the flexor retinaculum.

Nerve supply. It is supplied by a branch from the medial popliteal nerve (L. 5 and S. 1).

Actions. It assists the gastrocnemius in its action.

STRUCTURES CONTAINED IN THE INTERMEDIATE COMPARTMENT:

Flexor hallucis longus. *Origin.* It lies on the lateral side of the leg and arises from the lower two-thirds of the posterior surface of the shaft of the fibula except its lower one inch, from the interosseous membrane, from the crural intermuscular septum and from the fascia covering the tibialis posterior muscle.

Insertion. The muscular fibres from either side end in a tendon which occupies almost the whole length of its origin and lies on the middle of the back of the muscle (bipennate muscle); the terminal cord-like tendon of the muscle passes successively through the groove behind the lower end of the tibia, groove on the posterior surface of the talus and that beneath the sustentaculum *tali of the calcaneum and* then passes to the sole of the foot by crossing the tendon of the flexor digitorum longus from lateral to the medial side and is finally inserted into plantar aspect of the base of the distal phalanx of the great toe.

Nerve supply. It is supplied by the posterior tibial nerve (L. 5 and S. 1, 2).

Actions. It flexes the distal phalanx of the great toe and in continued action flexes the remaining phalanx of the great toe and plantar-flexes the ankle joint; it maintains the longitudinal arch of the foot.

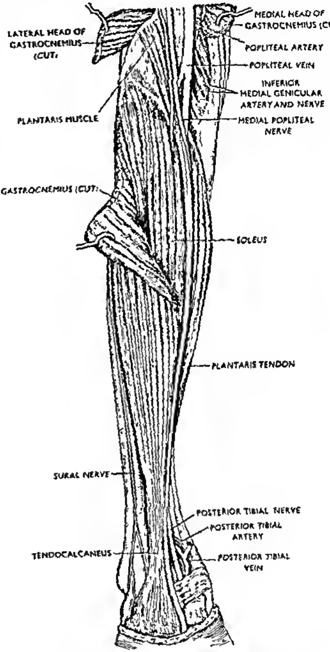


Fig. 568. The back of the left leg. The gastrocnemius has been separated from its origin to show the soleus and the tendon of the plantaris muscle.
From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

Flexor digitorum longus. *Origin.* It lies on the medial side of the back of the leg and arises from the posterior surface of the tibia medial to the tibialis pos-

terior muscle and below the soleal line; the fibres of origin extend downwards upto a point about 3 inches above the lower end.

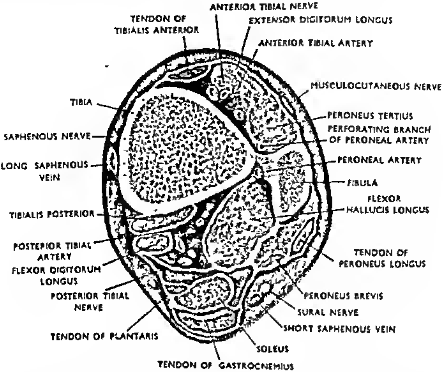


Fig. 569. A transverse section across the right leg. With the kind permission from Lederle Laboratories—drawn by Mr Paul Peck.

Insertion. The muscular fibres end in a tendon which occupies almost the whole length of the back of the muscle and then as it descends downwards it crosses the tendon of the tibialis posterior and passes through the groove behind the lower end of the tibia beneath the flexor retinaculum. Then crossing the tendon of the flexor hallucis longus from medial to lateral side it enters the sole of the foot where it is expanded and after joining with the tendon of the flexor digitorum accessorius divides into four tendons which are inserted into the plantar aspects of the distal phalanges of the second, third, fourth and the fifth toes.

Nerve supply. It is supplied by the posterior tibial nerve (L. 5 and S. 1).

Actions. It flexes the distal phalanges of the second, third, fourth and the fifth toes and in the continued action flexes the other phalanges of the same toes and plantar flexes the ankle joint. It also maintains the longitudinal arch of the foot.

Tibialis posterior. It is the deepest muscle on the back of the leg and lies in between and partly under cover of the flexor digitorum longus and the flexor hallucis longus. The former is on its tibial side and the latter on its fibular side. It arises from the lateral area of the posterior surface of the shaft of the tibia between the commencement of the soleal line above and the junction of the middle with the lower-third of the shaft, from the medial grooved part of the posterior surface of the fibula, from the back of the crural interosseous membrane, from the transverse intermuscular septum and from the intermuscular septa between it and the adjacent muscles. It soon ends in a tendon which crosses deep to the flexor digitorum longus tendon to gain its medial side and lies under cover of the flexor retinaculum and superficial to the deltoid ligament. Then the tendon passes to the plantar aspect of the plantar calcaneo-navicular ligament (spring ligament) where it receives its principal insertion into the tuberosity of the navicular bone. From here it sends out slips of insertion—one passes backwards to be inserted into the sustentaculum

tali of the calcaneum and the others spread out and are inserted into the plantar aspects of all the remaining tarsal bones except the talus and to the bases of all the metatarsal bones except the first and the fifth.

The upper end of the muscle as it arises from the tibia and the adjoining portion of the fibula forms an U-shaped gap through which the anterior tibial vessels pass to the front of the leg.

Nerve supply. It is supplied by posterior tibial nerve (L. 5 and S. 1).

Actions. It is the adductor and invertor of the foot and the plantar flexor of the ankle joint. It also maintains the longitudinal arch of the foot.

MUSCLES ON THE LATERAL ASPECT OF THE FIBULA:

Peroneus longus. It arises from the head of the fibula, from the proximal two-thirds of its lateral surface, from the lateral condyle of the tibia and also from the deep fascia and the intermuscular septum. It forms a tendon which lies in a groove behind the lateral malleolus, comes forward on the lateral side of the calcaneum below the peroneal tubercle and then curving medially it runs forwards in a groove in the cuboid bone and is inserted into the infero-lateral side of the base of the first metatarsal and medial cuneiform bones.

Nerve supply. It is supplied by the musculocutaneous nerve of the leg.

Actions. It causes the :rtion of the foot and by ssing transversely across : sole of the foot it mains the transverse arch of : foot. It also maintains : lateral longitudinal arch the same. In continued tion it is the plantar flexor the ankle joint.

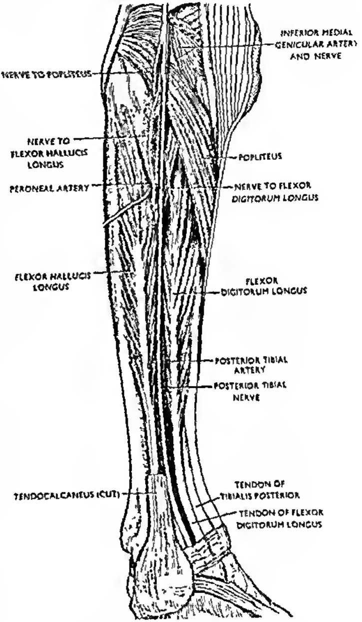


Fig. 570. The deep muscles on the back of the left leg after removal of the gastrocnemius and the soleus.

From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

Peroneus brevis. It takes its origin from the lower two-thirds of the lateral rface of the shaft of the fibula in front of the peroneus longus and from the anterior d posterior crural intermuscular septum. Lower down it fibres form a tendon iich passes behind the lateral malleolus of the fibula and lies in front of the pereus longus. Then it passes above the peroneal tubercle on the lateral surface of

the calcaneum and further passes forwards and laterally to be inserted into lateral side of the tubercle at the base of the fifth metatarsal bone.

Nerve supply. It is supplied by the musculocutaneous nerve of the leg.

Actions. It is one of the evertor of the foot and supports the ligaments which are stretched due to over-inversion of the foot.

Flexor Retinaculum of the foot. It is a strong fibrous band which stretches across the medial side of the ankle joint and connects the posterior margin of the medial malleous to the tuberosity of the calcaneum. Above it is continuous with the deep fascia of the leg and below with the plantar aponeurosis. It gives origin to the abductor hallucis from its lower part. It protects the posterior tibial vessels and nerve in this situation and conceals under it the posterior tibial vessels and nerve and the three flexor tendons (tibialis posterior, flexor digitorum longus and the flexor hallucis longus). It is covered by the skin and superficial fascia and *is pierced by medial calcaneal vessels and nerves.*

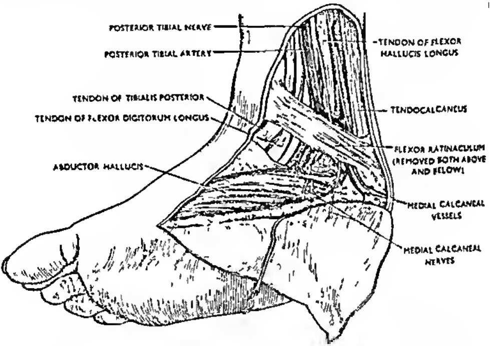


Fig. 571. The medial aspect of the right ankle and the adjoining areas to show the structures under the flexor retinaculum which has been removed both above and below. From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

Structures in deep relation to the flexor retinaculum. From medial to lateral side the structures under cover of the flexor retinaculum are as follows:

(1) Tendon of the tibialis posterior.
(2) Tendon of the flexor digitorum longus.
(3) Posterior tibial vessels.
(4) Posterior tibial nerve.
(5) Tendon of the flexor hallucis longus.

FUNCTIONAL CLASSIFICATION OF THE MUSCLES OF THE LEG:

(1) **Dorsiflexors of the ankle joint:**
(a) Tibialis anterior—Prime mover.
(b) Extensor digitorum longus.
(c) Extensor hallucis longus. } Synergists.
(d) Peroneus tertius.

(2) **Plantar flexors of the ankle joint:**
- (a) Gastrocnemius.
- (b) Soleus.
- (c) Plantaris.
- (d) Tibialis posterior. } Synergists.
- (e) Flexor hallucis longus and digitorum longus. }

(3) **Evertors of the foot:**
- (a) Peroneus longus.
- (b) Peroneus brevis.
- (c) Peroneus tertius.

(4) **Invertors of the foot:**
- (a) Tibialis anterior.
- (b) Tibialis posterior.

(5) **Extensors of the digits:**
- (a) Extensor digitorum longus.
- (b) Extensor hallucis longus.

(6) **Flexors of the digits:**
- (a) Flexor digitorum longus.
- (b) Flexor hallucis longus.

Plantar aponeurosis. The plantar aponeurosis is the deep fascia of the sole of the foot and consists of central, lateral and medial portions. The central portion is very thick and strong where as its lateral and medial portions are comparatively thin.

Central portion. It is roughly triangular and is wider in front and narrow behind. It covers the flexor digitorum brevis and is attached posteriorly to the medial tubercle of the calcaneum. Anteriorly opposite the heads of the metatarsal bones it divides into five digital processes, one for each toe. Opposite the metatarsophalangeal joint each of the digital slips divides into superficial and deep layers. The superficial layer blends with the skin of the transverse crease between the toes and the sole of the foot. The deep layer of each digital slip divides into two processes, one for each side of the flexor tendons for the toe, which pass upwards to fuse with the sides of the fibrous sheath of the flexor tendons of the toes and with the deep transverse ligaments of the sole of the foot. The central portion of the plantar aponeurosis at its point of divisions into digital slips, and for some distance in front, presents numerous transverse fasciculi which connect the digital slips together and with the skin. On either side the central portion of the plantar aponeurosis is continuous with its peripheral portions—medially, medial portion, and laterally, lateral portion. Two intermuscular septa, one on each side of the flexor digitorum brevis, pass dorsally into the sole; that on the medial side separates the flexor digitorum brevis from the abductor hallucis while the lateral one intervenes between the flexor digitorum brevis and the abductor digiti minimi.

Medial portion. The medial portion of the plantar aponeurosis covers the abductor hallucis and is comparatively thin. Posteriorly it is continuous with the flexor retinaculum of the foot and medially it is continuous with thè deep fascia on the dorsum of the foot along its medial margin. Laterally it is continuous with the central portion and at the junction between the two is the medial intermuscular septum which separates the flexor digitorum brevis from the abductor hallucis.

Lateral portion. It covers the abductor digiti minimi and is attached posteriorly to the lateral tubercle of the calcaneum. Laterally it is attached to the tubercle of the fifth metatarsal bone. Medially it is continuous with the central portion and at the junction there is a intermuscular septum which separates the flexor digitorum brevis and the abductor digiti minimi.

The muscle-layers at the sole. There are four different layers of muscles in the sole of the foot in order from superficial to the deep aspect and they are

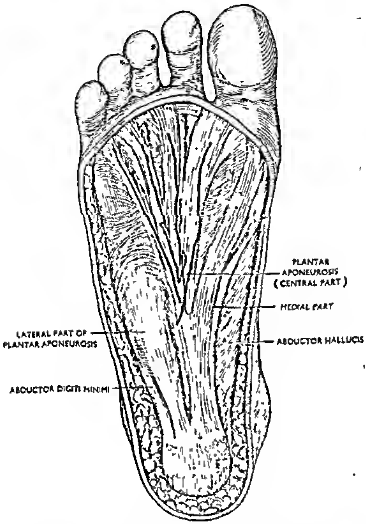


Fig. 572. The sole of the right foot to show the plantar aponeurosis. From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

classified into first, second, third and the fourth layers of muscles. The muscles in each layer are as follows:

First layer:

(1) Abductor hallucis.
(2) Abductor digiti minimi.
(3) Flexor digitorum brevis.

Second layer:

(1) Tendon of the flexor hallucis longus.
(2) Tendons of the flexor digitorum longus.
(3) Flexor digitorum accessorius.
(4) Lumbricales.

Third layer:

(1) Flexor hallucis brevis.
(2) Adductor hallucis (oblique and transverse head).
(3) Flexor digiti minimi brevis.

Fourth layer:

(1) The interosseous muscles—four dorsal interosseous and three plantar interosseous muscles.
(2) Tendon of the tibialis posterior.
(3) Tendon of peroneus longus.

MUSCLES OF THE FIRST LAYER

Abductor hallucis. It lies along the medial margin of the sole of the foot and connects the calcaneum with the great toe. It arises from the medial margin of the medial tubercle of the calcaneum, from the flexor retinaculum, from the plantar aponeurosis and from the intermuscular septum between it and the flexor digitorum brevis. It forms a tendon which together with the medial tendon of the flexor hallucis brevis is inserted into the medial margin of the proximal phalanx of the great toe. Its fibres of origin hide the plantar vessels and nerves which emerge into the sole of the foot under its cover.

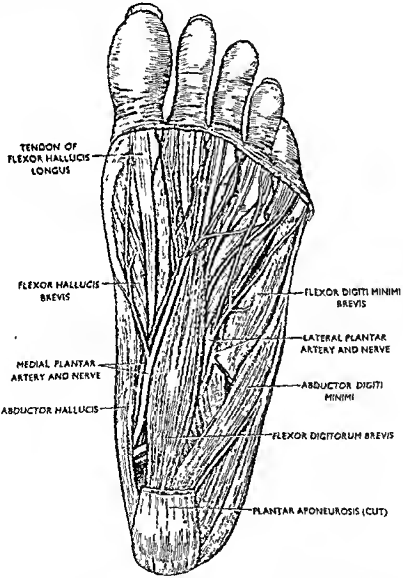


Fig. 573. The sole of the left foot to show the first layer of structures. From the dissection-hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

Nerve supply. It is supplied by the medial plantar nerve (L. 5 and S. 1).

Actions. It is the abductor and flexor of the proximal phalanx of the great toe.

Abductor digiti minimi. It arises from the medial and the lateral tubercles of the calcaneum, from the under-surface of the calcaneum in front of the medial and lateral tubercles, from the plantar aponeurosis and from the intermuscular septum between it and the flexor digitorum brevis. Together with the tendon of the flexor digiti minimi brevis it is inserted into the lateral side of the proximal phalanx of the little toe.

Nerve supply. It is supplied by the lateral plantar nerve (S. 1 and 2).

Actions. It is the abductor and flexor of the proximal phalanx of the little toe.

Flexor digitorum brevis. It is the most superficial muscle opposite the middle of the sole of the foot and lies immediately under cover of the central portion of the plantar aponeurosis. It arises by a tendon from the anterior part of the medial tubercle of the calcaneum and by fleshy fibres from the plantar aponeurosis (central portion) and from the lateral and medial intermuscular septa. It forms a muscular belly which ends in four tendons, one for each of the lateral four toes. Each tendon opposite the base of the proximal phalanx splits up into two slips for the passage of the corresponding tendon of the flexor digitorum longus and then reunites and finally splits into two slips which are inserted on either side of the middle phalanx of the corresponding toe. In its mode of insertion it is identical with that of the flexor digitorum superficialis (sublimis) in the palm.

Superiorly it is separated from the flexor digitorum accessorius by a thin layer of fascia and intervening between the two are the lateral plantar vessels and the nerve.

Nerve supply. It is supplied by the medial plantar nerve (L. 5 and S. 1, 2).

Actions. It flexes the middle phalanges of the four lesser toes.

MUSCLES OF THE SECOND LAYER

The intrinsic muscles of the second layer are the flexor digitorum accessorius and the lumbricales and besides these the tendon of the flexor hallucis longus and the tendons of the flexor digitorum longus will be found in this layer.

Flexor digitorum accessorius. It arises by lateral and medial heads which are separated from each other by the long plantar ligament. The larger *medial head* arises by muscular fibres from the hollowed out medial surface of the calcaneum. The smaller *lateral head* arises by tendinous fibres from the plantar surface of the calcaneum in front of the lateral tubercle and from the long plantar ligament. The two heads unite at an acute angle superficial to the long plantar ligament and then form a flattened band which is inserted into the deep aspect and the lateral margin of the flexor digitorum longus tendon. Through the latter tendon it reaches the phalanges of the second, third and the fourth toes.

Nerve supply. It is supplied by the lateral plantar nerve (S. 1).

Action. It assists in the work of the flexor digitorum longus and by its pull it tends to bring its tendons into a line with the toes on which they operate.

Lumbricales. The lumbricales muscles of the foot are four in number and are named numerically from medial to the lateral side. The first lumbricalis arises from the medial side of the first tendon of the flexor digitorum longus whereas the remaining three take their origin from the contiguous sides of the tendons of the flexor digitorum longus. Each muscle ends in a small tendon which runs forwards and upwards to reach the medial side of the corresponding toe and is inserted into the extensor expansion formed by the extensor digitorum longus.

Nerve supply. The first lumbricalis is supplied by the medial plantar nerve (L. 5 and S. 1) and the remaining three are supplied by the deep branch of the lateral plantar nerve (S. 1 and 2).

Actions. They prevent the hyperextension of the metatarsophalangeal joints and hyperflexion of the proximal interphalangeal joint of the four lesser toes.

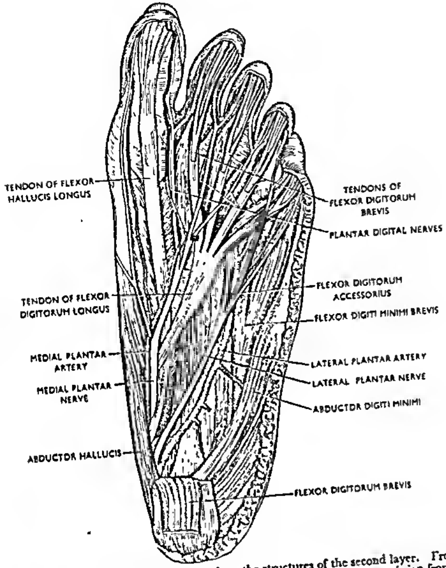


Fig. 574. The sole of the left foot to show the structures of the second layer. From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

MUSCLES OF THE THIRD LAYER

Flexor hallucis brevis. It arises by a narrow tendon from the medial part of the plantar surface of the cuboid bone behind the groove for the peroneus tendon, from the adjacent portion of the plantar aspect of the lateral cuneiform bone and from the tendon of the tibialis posterior which is inserted into the cuboid bone. The muscle fibres which succeed from the tendinous origin, arrange in a penniform manner to form lateral and medial portions. Each portion ends in a tendon which is inserted into the corresponding side of the base of the proximal phalanx of the great toe. The tendon from the medial portion blends with the tendon of abductor hallucis while that from the lateral portion blends with the tendon of adductor hallucis before insertion.

Nerve supply. It is supplied by the medial plantar nerve (L. 5 and S. 1).

Actions. It flexes the proximal phalanx of the great toe.

Adductor hallucis. It consists of two heads—oblique and transverse. The *blique head* arises from the plantar aspect of the base of the second, third and the fourth netatarsal bones and also from the sheath of the peroneus longus tendon. It forms

a tendon which blends with the lateral portion of the flexor hallucis brevis and is inserted into the lateral aspect base of the proximal phalanx of the great toe. The *transverse* head arises from the metatarsophalangeal ligament of the third, fourth, and the fifth toes and also from the deep transverse ligament of the foot. It joins the oblique head and is inserted along with the lateral part of flexor hallucis brevis to the lateral aspect of the base of the proximal phalanx of the great toe.

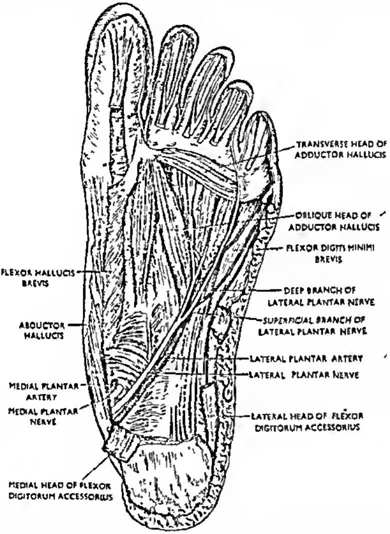


Fig. 575. The sole of the left foot to show the structures of the third layer. From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

Nerve supply. It is supplied by the deep division of the lateral plantar nerve (S. 1 and 2).

Action. Its oblique head is the adductor and flexor of the great toe, its transverse head is the adductor for all the toes.

Flexor digiti minimi brevis. It arises from the medial part of the base of the fifth metatarsal bone and from the sheath of the tendon of the peroneus longus. It forms a tendon which is inserted into the lateral side of the base of the proximal phalanx of the little toe.

Nerve supply. It is supplied by the superficial branch of the lateral plantar nerve (S. 1 and 2).

Actions. It is the flexor of the little toe.

MUSCLES OF THE FOURTH LAYER

The interossei muscles form the fourth layer of muscles and they consist of three plantar interossei and four dorsal interossei.

The *dorsal interossei* are bipennate muscles and each arises by two heads from the contiguous sides of the metatarsal bones and occupies the intermetatarsal space. Each ends in a tendon and is inserted as follows. The first dorsal interosseous is inserted on the medial side of the proximal phalanx of the second toe and the remaining three muscles are inserted on the lateral side of the proximal phalanges of the second, third and the fourth toes.

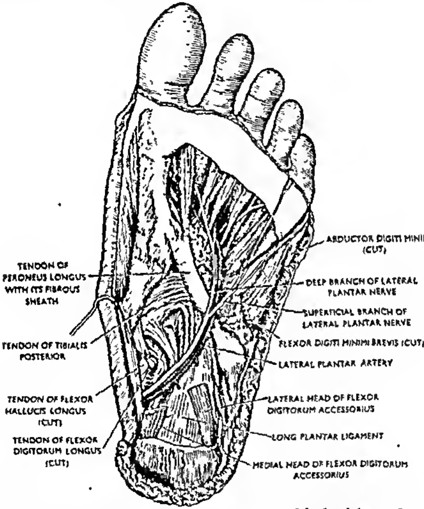


Fig. 576. The sole of the left foot to show the structures of the fourth layer. From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

The *plantar interossei muscles* are three in number and they arise by a single head from the medial aspect of the base and shaft of the third, fourth and the fifth metatarsal bones. They are inserted by a small tendon into the same aspect of the proximal phalanx of the corresponding toes.

Nerve supply. The first and second plantar interossei and the first, second and the third dorsal interossei are supplied by the deep branch of the lateral plantar nerve. The third plantar interosseous and the fourth dorsal interosseous are supplied by the superficial branch of the lateral plantar nerve.

Actions. The dorsal interossei muscles abduct the toes from an imaginary plane drawn through the axis of the second toe, and concurrently with the abduction they

extend the toes with the exception of the little toe. The plantar interossei cause adduction and flexion of the third, fourth and the fifth toes.

Neurological value of the muscles of the leg and the foot:

(1) *Muscles supplied by the anterior tibial nerve*—(L. 4, 5 and S. 1):
(*a*) Tibialis anterior.
(*b*) Extensor hallucis longus.
(*c*) Extensor digitorum longus.
(*d*) Peroneus tertius.
(*e*) Extensor digitorum brevis.
(*f*) First and second dorsal interossei muscles.

(2) *Muscles supplied by the posterior tibial nerve:*
(*a*) Flexor digitorum longus (L. 5 and S. 1).
(*b*) Flexor hallucis longus (L. 5 and S. 1, 2).
(*c*) Tibialis posterior (L. 5 and S. 1).

(3) *Muscles supplied by the musculocutaneous nerve of the leg:*
(*a*) Peroneus longus (L. 4, 5 and S. 1).
(*b*) Peroneus brevis (L. 4, 5 and S. 1).

(4) *Muscles supplied by the medial plantar nerve:*
(*a*) Abductor hallucis (L. 5 and S. 1).
(*b*) Flexor digitorum brevis (L. 5 and S. 1, 2).
(*c*) Flexor hallucis brevis (L. 5 and S. 1).
(*d*) First lumbricalis (L. 5 and S. 1).

(5) *Muscles supplied by the lateral plantar nerve:*
(*a*) Abductor digiti minimi (S. 1 and 2).
(*b*) Flexor digitorum accessorius (S. 1).
(*c*) Flexor digiti minimi brevis (S. 1 and 2).
(*d*) All the interossei muscles (S. 1 and 2).
(*e*) Second, third and the fourth lumbricales (S. 1 and 2).
(*f*) Adductor hallucis (S. 1 and 2).

CIRCULATORY SYSTEM

THE BLOOD VESSELS

General consideration. The blood vessels are hollow tubes carrying blood and consist of arteries and veins. The arteries carry blood away from the heart to the periphery and are likened to the tree with its branches; all the arteries contain oxygenated (pure) blood except the pulmonary artery which contains deoxygenated (impure) blood. The veins convey blood from the periphery to the heart and are likened to the river with its tributaries; they contain deoxygenated (impure) blood except the pulmonary veins which contain oxygenated (pure) blood.

The heart, an automatic muscular pump, consists of four chambers, two atria, right and left, and two ventricles, right and left. Two great veins, the superior and inferior venae cavae, carry impure blood to the right atrium of the heart from where blood flows to the right ventricle through an orifice, the right atrio-ventricular orifice; from the right ventricle the impure blood is conveyed to the lungs through the pulmonary trunk and its branches, and after being purified (oxygenated) in the lungs, it flows back to the left atrium of the heart through the pulmonary veins; the purified blood from the left atrium passes to the left ventricle through the left atrio-ventricular orifice and the same is discharged from the left ventricle through the great arterial trunk, the aorta, and then through its branches, to the different parts of the body. Thus it appears that the heart distributes

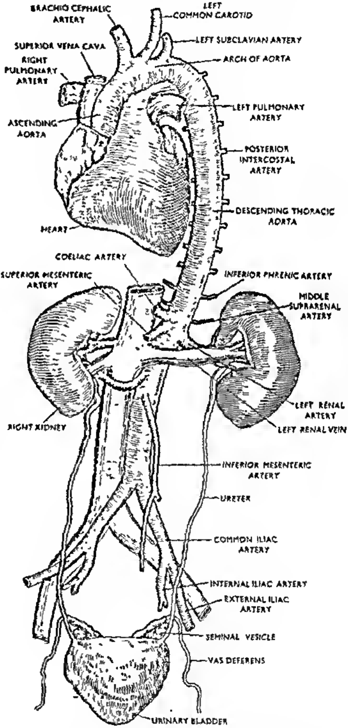


Fig. 577. The heart with its distributing trunks. From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

oxygenated blood to the different tissues of the body through the aorta and its branches from its left ventricle, and also sends impure blood to the lungs for purification through the pulmonary trunk and its branches from the right ventricle. Thus the ventricles act as distributing chambers whereas the atria are receiving chambers.

The main systemic artery, that is, the aorta, and the pulmonary trunk, each measures about 1½ inches in diameter; both these main trunks branch and re-branch like a tree and ultimately become much smaller in size which are just visible to the naked eyes and are known as the *arterioles* which measure about 150μ or less in diameter. The arterioles further break up into minute branches which are not visible to the naked eyes and these minute branches are known as the *capillaries* (L. capillus=hair). Each capillary measures about ½ to 1 mm. in length and about 8 to 10μ in diameter. Thus red blood corpuscles, which measure about 7μ in diameter can pass through a capillary in a single file.

Where a capillary ends, the smallest vein, which is known as a *venule*, begins as a continuation of the capillary and gradually becomes larger and larger as different venules join together to form a *vein*; similarly smaller veins join together to form a larger vein and ultimately only two large veins, the *Superior* and the *Inferior* venae cavae succeed in reaching the heart where they end by opening into its right artrium. Thus, it appears that the heart pumps out blood through its arterial system into the different parts of the body and the same (after being depleted of its oxygen) is returned back into the heart by veins and this is what is known as the *circulation of blood*.

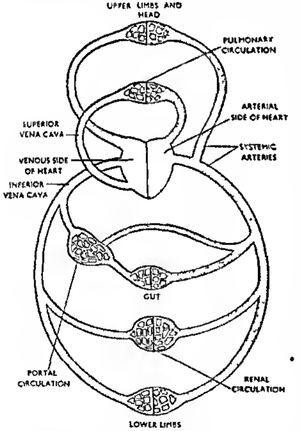


Fig. 578. The circulation of blood. (Diagrammatic).

The circulation of blood through the aorta and its branches and its return into the heart by the superior and inferior venae cavae are known as the *Systemic Circulation*. Under the Systemic Circulation there are smaller fields of circulation such as *hepatic circulation*, *renal circulation*, *splenic circulation* and *cavernous circulation* which deserve special mention and have been discussed in the appropriate places.

The musculature of the heart itself is fed by the coronary arteries (Right and Left) which arise from the ascending aorta, and the deoxygenated blood from the musculature of the heart returns into the right atrium of the heart through the coronary sinus and by other smaller veins and this constitutes the *Coronary Circulation*.

The circulation of blood through the pulmonary trunk and its branches into the lungs for oxygenation and its return into the heart by the pulmonary veins constitute the *Pulmonary Circulation*.

Structure of arteries. Histologically all arteries consists of three coats or tunics namely, the *tunica externa or adventitia*, the *tunica media* and the *tunica intima* from without inwards.

Tunica Externa or Adventitia. **This is the outermost layer of an artery and is formed mostly by collagen fibres, a few elastic fibres, fibroblasts and the periarterial**

plexus of nerves. The structures of this layer are disposed longitudinally along the course of the artery. The vasa vasorum, when present, penetrate through this layer into the tunica media.

Tunica Media. This is the middle coat and intervenes between the tunica adventitia externally and tunica intima internally and *is formed by both muscular and elastic tissues.* The type of an artery is usually dependent on the presence of the relative amount of the above tissues. In elastic type of arteries the elastic fibres predominate, whereas in the muscular type, the muscular tissue predominates. The *elements of this layer are usually disposed circularly around the vessel.* Externally this layer is occasionally separated from the tunica adventitia by a thin layer of elastic membrane known as the *external elastic lamina* and internally by the *internal elastic lamina* which intervenes between it and the tunica intima.

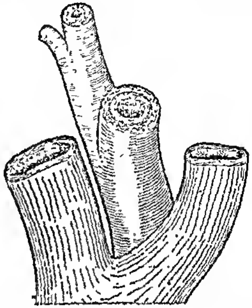


Fig. 579. Arteries and veins. (Diagrammatic).

Tunica Intima. This is the innermost layer and is formed by a layer of flattened endothelial cells. Underlying the endothelium is the loose subendothelial connective tissue and is separated from the tunica media by a layer of elastic membrane known as the *internal elastic lamina.* The elastic fibres of this lamina usually run longitudinally.

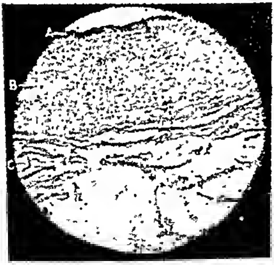


Fig. 580. The structure of a medium-sized artery. (Microphotograph).

A= Tunica intima.
B= Tunica media.
C= Tunica adventitia.

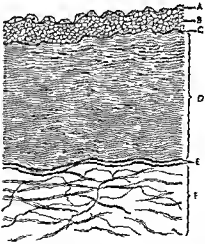


Fig. 581. The structure of a sized artery. (Diagrammatic).

A= Endothelial lining.
B= Subendothelial layer.
C= Internal elastic lamina.
D= Tunica media.
E= External elastic lamina.
F= Tunica adventitia.

Difference between an artery and a vein:

	Artery	Vein
Walls	Thicker in consistency and elastic. Consists of three coats and from without inwards, they are tunica adventitia (fibrous), tunica media (muscular), and tunica intima (endothelial).	Thinner in consistency and inelastic. Consists of three coats like the artery but much thinner in comparison.
Lumen	Lumen increases with each gush of blood and there is no valvular arrangement. Comparatively smaller in calibre.	Lumen is constant and has valvular arrangements. Comparatively larger in calibre.
Flow of blood	Flow is continuous with intermittent extra jerky load and is distributed from the centre (Heart) to the periphery. Rate of flow faster.	Flow is continuous and passes from the periphery to the centre (Heart). Rate of flow slower.
Character of blood	Carries pure blood (except the pulmonary arteries).	Carries impure blood (except the pulmonary veins).

CLASSIFICATION OF ARTERIES

According to structure:
- (a) Elastic type.
- (b) Muscular type.
- (c) Mixed type.
- (d) Hybrid type.

According to size:
- (a) Large arteries (Elastic type).
- (b) Medium arteries. } Muscular type.
- (c) Small arteries or arterioles. } Muscular type.

Other types:
- (a) End-arteries.
- (b) Vasa vasorum.
- (c) Helicine arteries.

Elastic type. The elastic type of arteries are formed by the main arterial trunks where elastic fibres predominate and almost replace the muscle fibres in the tunica media, which are few and scanty. These types of arteries are specially adapted to meet the tensile force exerted by the column of blood discharged with each systole (contraction of ventricles) of the heart. By virtue of the presence of elastic fibres the walls of these arteries yield sufficiently to the pressure with each gush of blood and at once recoil back to their original form, and thus assist in propelling the blood to the periphery.

Muscular type. In the *muscular type of arteries* the muscular coat in the tunica media becomes conspicuously prominent and well-formed. The vasomotor nerves control these arteries and depending on the local conditions these arteries either dilate or contract under the influence of the vasomotor nerves so as to regulate the flow of blood to the capillary bed. Besides this the terminal arterioles are known to contract rythmically at frequent intervals which enable them to propel the blood through the capillaries.

Mixed type. The arteries branch and re-branch like a tree and become gradually smaller, in other words, structurally one type of arteries pass on to the other and

the transition is usually gradual. The intermediate portion of an artery which is undergoing transition from one to the other type, is a mixed type of artery structurally. The axillary, the external carotid and the common iliac arteries are of mixed types.

Hybrid type. When either the mixed or the elastic type of arteries suddenly change into the muscular type, they are called hybrid type of arteries. The visceral branches of the abdominal aorta are of hybrid types.

Regional peculiarities. The *arteries supplying the different organs* vary from each other considerably, as for example, the arteries of the white pulp of the spleen. In the white pulp the tunica adventitia is replaced by a tubular sheath of lymphocytes. Similarly, the adrenal cortical vessels run into sinusoidal vessels within the cortex.

The *muscular tissue of the tunica media of the arteries of the lower limb* is more well-developed than those of the upper limb.

The *arteries within the skull* are thin-walled, their internal elastic lamina are well-developed and there is none or very little elastic fibres in the tunica media. These arteries, being confined within the rigid cranial wall, are neither exposed to external influences, nor they can expand considerably and for these reasons their walls are thin.

In the *umbilical artery* the tunica intima has no internal elastic lamina and is formed only by the endothelium. The tunica media is very much well-developed consisting of two thick muscular layers, outer circular and inner longitudinal. At some places the longitudinal fibres are absent.

End-arteries. The end-arteries are those which have no *pre-capillary anastomosis with any other adjacent arteries*. Therefore, due to some reason or the other, when their lumen becomes occluded, the tissues supplied by them are cut off from their nutrition and ultimately they die resulting in either gangrene or infarction. The interlobular arteries of the kidney, the vasa recta of the mesentery, the arteries within the spleen and the central artery to the retina are examples of end-arteries.

In some situations, a particular artery might have pre-capillary anastomosis with adjacent arteries but, in the event of obstruction in these arteries, collateral circulation fails to occur to such an extent as is necessary to maintain healthy funcrion of the part concerned. Such arteries, inspite of having collateral anastomosing connections behave like end-arteries and are known as *functional end-arteries*. Thus end-arteries may be either *anatomical* (having no pre-capillary anastomosis) or *functional*. The coronary arteries of the heart and the appendicular artery are examples of functional end-arteries.

Vasa vasorum. These are small arteries which supply the walls of the larger and medium-sized blood vessels. They are derived either from the main trunk or from the adjacent arteries and penetrate into the walls of the large—and medium sized arteries and veins. They supply the tunica adventitia and a part of the tunica media. The rest of the walls of these blood vessels are supplied by diffusion of nutrient material from the contained blood within the lumen of these vessels.

Helicine arteries of the penis. These arteries form a group by themselves and are peculiar to other arteries in that, instead of ending into the capillary bed, they end by opening into irregular, dilated spaces known as the *cavernous spaces* which are lined by endothelial-like flattened cells. These lining cells are continuous with the lining endothelium of the feeding artery on one side and with the endothelium of the emerging vein on the other side. Here the cavernous spaces take the place of the capillaries in other tissues. The circulation of blood from the arterioles to the cavernous spaces and then to the veins constitutes what is known as *cavernous circulation*. The helicine arteries are structurally peculiar in that their *intimal layer presents a corrugated appearance*.

While the vessels are empty these ridge-like elevations, by their close apposition, shut off the lumen of the vessels partially. It seems that this mechanism allows the cavernous spaces to remain decongested during flaccid condition of the penis. By nervous influence these vessels open up and the cavernous spaces become rapidly filled up causing expansion and elongation of the penis. Expansion of the cavern-

ous tissues causes distension of the rigid penile fascia which mechanically obstructs the flow of blood from the deep dorsal veins of the penis thereby causing stiffness and erection of the penis.

Arterial anastomosis. Arteries are often found to anastomose with one another in the region of their distribution, particularly over the region of the joints. It seems that inter-connection of arteries in the form of anastomosing-network is a means of establishing collateral circulation, in case, one of the distributing arteries is blocked. Moreover arterial anastomosis is a device to maintain steady arterial pressure in those parts which are subjected to frequent movement such as the region of the joints, and also it helps in maintaining uniform arterial pressure in the region of the distribution.

There are two types of arterial anastomosis namely, *actual* and *potential*.

Actual arterial anastomosis. Here the arteries anastomose end to end and when divided, blood spurts out from both ends of the divided vessel. In case of occlusion of any member of such an anastomosis, nutrition of the tissues under the control of these arteries does not suffer because of the free anastomosis. The anastomosis between the right and the left gastric arteries along the lesser curvature of the stomach, between the ovarian and uterine arteries, between the inter-costal arteries and that between the labial branches of the facial artery in the upper and the lower lips, are examples of actual arterial anastomosis.

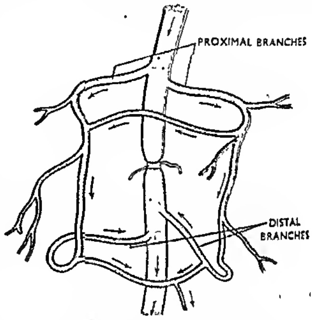


Fig. 582. Actual anastomosis between proximal and distal branches and the routes of collateral circulation after ligature of the main artery. (Diagrammatic).

Potential anastomosis. In potential anastomosis there is pre-capillary anastomosis between the terminal arterioles of adjacent arteries. Under this condition occlusion of any member of the anastomosing arteries affect badly the nutrition of the tissues concerned as an immediate effect, because the anastomosing channel is too narrow to cope with the demands. However, provided that sufficient time is allowed, the anastomosing channels may dilate considerably to meet the demands. The anastomosis between the coronary arteries, the arterial anastomosis around the joints and that between the cortical arteries of the cerebral hemispheres are examples of potential anastomosis.

Mode of termination of an arteriole. As it has already been said that an arteriole usually terminates by running into (1) a *capillary bed* which is drained by the venules. Depending on the tissues they supply, the capillary pattern varies widely, as for example, in the nail bed they form irregular fish-hook-shaped loops whereas in the kidney, they form glomerulus—the terminal *afferent arteriole* ends into a series of arched loops which are joined together on the other end to form the *efferent arteriole* which is again thrown into capillary bed which is drained by the venule.

(2) An arteriole instead of running into capillary bed may end into sinusoids as in the liver, bone marrow, etc.

(3) It may terminate into cavernous spaces instead of breaking into capillaries.
(4) It may terminate into irregular spaces formed by a network of cells—open pulp circulation of spleen.

Functions of the arteries. When we think about the functions of the arteries it is better we look into their structure. They are tubular structures with elastic walls consisting of three tunics which have already been discussed. They carry blood in their lumen and transport it to various parts of the body and feed the capillary system through which the tissues get their nourishment. The flow of blood through them is continuous with intermittent additional gush corresponding to the systole of the heart. The driving force of the heart is responsible for the discharge and circulation of the extra load during systole but during diastole, when the heart is at rest, the driving force required for circulation is taken over by the arterial walls which by their elastic recoil on the contained blood, acquire a driving force necessary for circulation. Therefore, the elastic nature of the arterial walls is responsible for circulation and maintenance of B. P. during diastole. Moreover, the coronary arteries of the heart, which by their origin opposite the aortic valves, are deprived of the driving force of the contractile heart for their filling and circulation within them, because during the systole the valves are compressed against the walls of the aorta which closes the month of the coronaries. When the aortic valves close during diastole the mouths of the coronaries remain open and it is the elastic recoil of the aortic wall which drives the blood into them for circulation. Thus the functions of the arteries may be summarised as follows:

(1) Transport of blood to the capillary system through which the tissues get their nourishment.
(2) The elastic recoil of the arterial wall (elastic type) on the contained blood, acquire a driving force which maintains the circulation during diastole when the heart is at rest.
(3) The muscular type of arteries, either by contraction or by relaxation, decrease or increase the flow of arterial blood in a particular region of the body respectively. These activities of the muscular type of arteries are controlled by the vasoconstrictor and the vasodilator nerves respectively.
(4) Maintains blood pressure.
(5) Maintains coronary circulation.

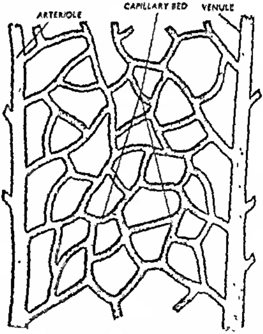


Fig. 583. The capillary bed. (Diagrammatic).

Capillaries. The capillaries are minute vascular channels given out by the terminal arteriole, arranged in the form of a network known as the *capillary bed* and are invisible to the naked eyes. The cross-section of the capillary bed is much greater than the lumen of its feeding artery and thus the capillary bed provides a means by which the blood is widely dispersed into the tissues. The term 'capillary' is derived from the latin word 'Capillus' meaning a hair because they have a semblance to that structure. The blood from the capillary bed is drained into the smallest vein known as the *venule*.

Histologically each capillary is formed by a single layer of endothelial cells which are arranged longitudinally and are held together by a minimum of cementing substance in between the cells. Surrounding the endothelial tube, in some capillaries, is a delicate layer of connective tissue (perithelium) which separates it from

the surrounding structures. In addition to a few scattered fibroblasts, macrophages and a variety of more primitive cells resembling the embryonic mesenchyme cells known as the *adventitial cells* and cells with branching processes known as the *Rouget cells* or *pericytes* are also found in the walls of the capillary tube. The function of the Rouget cells is still a matter of controversy, although, at one time it was believed that they were concerned in the contractility of the capillary wall.

Each capillary usually measures about ½ to 1 mm. in length and about 8 to 10μ in diameter and thus R.B.Cs can run in the capillaries in a single file.

Capillary patterns. Normally a terminal arteriole breaks up into a network of minute vessels, which are invisible to the naked eye, and are drained by the venules. This is the usual or *typical pattern* in most of the tissues, although, depending on the functions, there are some variations in the mode of arrangement of the networks in some tissues. In the intestinal villi the capillaries form a complex network, in the muscle they are arranged in longitudinal vessels running between the parallel fibres and cross connected to one another by short branches, in the nail bed the capillaries are arranged in characteristic fish-hook-like loops. In the kidney the capillaries are arranged in a special formation known as the *glomerulus* which consists of a complicated capillary loop which has a feeding artery, the *afferent artery* and a draining artery, the *efferent artery*.

Properties and functions of the capillary wall. Contractility, elasticity and permeability are the essential properties of the capillary wall and for these, the capillaries are greatly concerned in tissue nutrition and tissue metabolism.

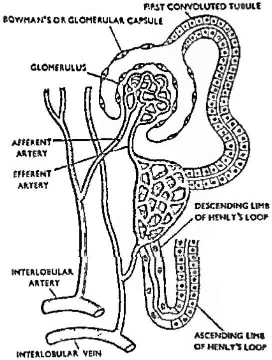


Fig. 584. The capillaries in glomerular formation in the kidney.

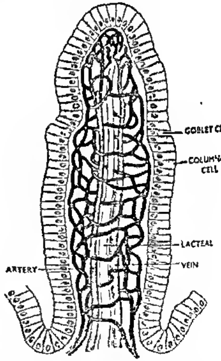


Fig. 585. The capillary pattern in an intestinal villus.

Sinusoids. In some organs namely, liver, bone marrow, spleen, adrenal gland, etc., the connections between the arteries and the veins, instead of being formed by capillaries, are effected by some vessels of irregular outline known as the *sinusoids*. The sinusoids have no constant bore which vary from 5 to 20 microns in diameter or more. Structurally, their walls are not formed by a continuous lining of endothelial cells but instead, they are made up of both endothelial and phagocytic

cells. Unlike the capillaries the outlines of the cells are not demonstrable after treatment with silver nitrate in most cases. The walls of the sinusoids are accompanied by a membranous networks of reticular fibrils.

The differences between the capillaries and the sinusoids are given below in a tabular form.

Differences between a capillary and a sinusoid:

	Capillary	Sinusoid
Walls & Lumen	Have regular outline with uniform bore.	Have irregular outline with irregular bore which varies from 5 to 20 microns or more.
Structure	Structurally lined continuously by a single layer of endothelium surrounded by the perithelium. The outlines of the cell bodies can be demonstrated clearly by treatment with silver nitrate solution.	Structurally lined by both endothelial and phagocytic cells and are surrounded by a network of reticular fibrils. The outlines of the cell bodies cannot be established definitely by treatment with silver nitrate solution.
Development	They develop as endothelial tubes.	Develop as wide blood spaces which are subsequently subdivided into irregular spaces by the developing tissues within which they are situated.

Arterio-venous anastomosis. Contrary to the former belief that arteries never open into the veins directly except through the capillary bed, it is now known that direct arterio-venous communication not only exists but they are fairly widespread in the human body. In this anastomosis the terminal arteriole before terminating into the capillary bed gives off a short branch which directly opens into a vein. This type of anastomosis is usually present in the skin, particularly in the hand and digits, in the mucous membrane of the nose and intestine, the thyroid gland and in the sympathetic ganglion. Direct communication between the vein and the artery is a normal feature in the placenta. In the foetus also arterio-venous anastomoses are quite frequent.

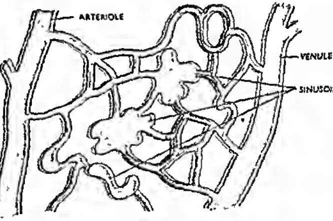


Fig. 586. The sinusoidal termination of the arteriole.

The arterio-venous anastomosis is a means of short-circuiting the circulation whenever it is necessary.

The communicating channel between the artery and the vein (arterio-venous anastomosis) has well-developed circular muscular coat in its wall which is controlled by the vasomotor nerves. Depending on the local needs, this muscular coat either contracts or relaxes thus behaving like a 'sphincter'. When it contracts, the anastomosis becomes 'closed' and the blood has to pass through the capillary bed before it can pass to the veins. When it relaxes, the anastomosis becomes

'open' and the blood is short-circuited into the vein without having passed through the capillary bed. By this short-circuiting arrangement a greater amount of blood can circulate in a particular area in a short time, but at the same time, the blood having no access into the capillary bed, gets no chance to be utilised by the tissues because the latter can only be nourished by the blood when it has passed through the capillaries. Therefore, it appears that when the arterio-venous anastomosis operates the nutrition of the tissues suffers but at the same time, local warmth improves due to greater amount of blood circulating in the area. Thus the arterio-venous anastomosis is considered to be a device to prevent the chilling effects and this is well-understood when location of such anastomoses, such as in the skin, toes, fingers and in the nasal mucous membrane, is taken into account.

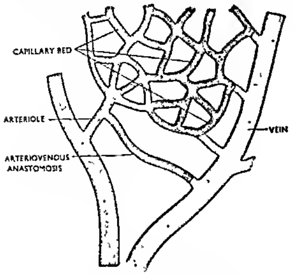


Fig. 587. The arrangement of arterio-venous anastomosis.

Age-changes in the arteries. The age-changes in the arteries are slow processes in which the earliest blood vessels of embryonic life, which consist of simple endothelial tubes, develop gradually into fully formed arteries by about 25th to 30th years of life after birth. Afterwards regressive changes appear slowly and become well-established in the old age. Thus the age-changes in the arteries may be discussed under two heads, *physiological changes* and *regressive changes*.

PHYSIOLOGICAL CHANGES. The physiological age-changes in arteries are not the same in the two main types of arteries (elastic and muscular) but they differ in details as follows:

Elastic type of arteries. In a four month's old human embryo, the elastic type of arteries, as is seen in the aorta, are seen to consist of three main layers, tunica intima, tunica media and tunica adventitia. The *tunica intima* consists of the endothelial lining and the internal elastic lamina. The tunica media consists of several layers of circular muscle fibres and flat networks of elastic fibres which intervene between the muscle layers. The *tunica adventitia* forms a thick layer, thicker than the tunica media, and consists of embryonic connective tissue. Later on, during the end of the intraembryonic life the internal elastic lamina becomes thicker, the flat networks of elastic fibres in the tunica media become condensed into several thick membranes, the muscular layer becomes slightly thicker but the tunica adventitia becomes slightly smaller in thickness. After birth the number and the thickness of the elastic membrane in the tunica media both increase gradually and a elastic muscular layer develops in the intimal layer which intervenes between the endothelium and the internal elastic membrane or lamina. At about the age of 25th year the differentiation of all these layers are complete.

Muscular type of arteries. During mid-embryonic life a muscular type of artery, such as the brachial, consists of the usual three layers; the intimal layer consists of the endothelial lining and a well-defined internal elastic lamina; the tunica media consists of the smooth muscle layer and the tunica adventitia contains a well-defined external elastic lamina and a surrounding connective tissue layer. Subsequently the three layers of the arterial wall become gradually thicker but the media becomes the thickest layer sharply demarcated by the external and internal elastic laminae. After birth, a connective tissue layer develops gradually between the endothelium and the internal elastic lamina.

Regressive Changes. *Elastic type of arteries.* In the elastic type of arteries, such as the aorta, the tunica intima becomes irregularly thick and fat infiltrates into its intertices and ultimately degenerative changes commence to proceed to *arteriosclerosis.* In the tunica media the elastic membranes become degenerated in which the *elastin,* which is responsible for the elasticity of the elastic fibres, is converted into *elacin,* a non-elastic substance.

In the *muscular type of arteries* the main change is the *calcification within the tunica media.* There is also thickening of the tunica intima due to splitting of the internal elastic lamina and new formation of collagen and elastic fibres.

Growth and repair. The blood vessels can proliferate throughout life, particularly in the embryonic life and during the growing period. The growth of the blood vessels is manifested in two forms, either by multiplication of the capillaries by proliferation, or by enlargement of the existing vessels.

Depending on the demands, some of the existing capillaries may regress while some new ones may be formed in a new direction or they replace the old ones damaged by usual wear and tear. The capillaries grow by the process of 'sprouting' in which, from the summit of a existing capillary loop the endothelial cells proliferate to form solid buds. Later on, these solid buds enlarge, canalised and become continuous with the parent stem and allow the blood to flow into them.

In some conditions, as in the obstruction in an artery its anastomosing collaterals sufficiently enlarge to maintain the circulation. The capillaries may also enlarge sufficiently and may acquire secondary coat to meet the local demands.

When an artery is completely divided the walls of its cut-ends retract considerably due to the presence of the elastic fibres. When it is partially divided, its walls retract from the site of the injury resulting in a button-hole opening in its wall. In the healing of wounds the capillaries play an important role. They proliferate quickly by the process of 'sprouting' and the pericapillary fibroblasts multiply to form the granulation tissue. The fibroblasts lay down collagen fibres and the wound is healed by the formation of the scar tissue.

THE VEINS

The veins are likened to the river with its tributaries and carry the deoxygenated blood (except the pulmonary veins) from the tissues to the heart in a continuous stream. Compared to the arteries, their walls are thinner, and are of larger calibre but the rate of flow is slower. The comparative larger calibre of the veins is explained by the fact that, in spite of their slow rate of flow, they are to empty the same amount of blood in a given time propelled through the arteries. Thus the larger calibre of the veins is a compensatory mechanism in relation to the slower rate of flow. Because of the low intraluminal pressure, their walls become less resistant and thinner. Moreover, for want of proper driving force, veins are to depend much on their external environment for efficient venous circulation and their thinner wall is an adaptation towards efficient circulation by extraneous influences in the form of pressure and compression. Veins usually accompany the arteries with which they are bound together by connective tissue. Large arteries are usually accompanied by a single vein whereas medium arteries, particularly those of the limbs, are accompanied by a pair of veins, one on each side and connected together across the artery by transverse veins at certain intervals. The paired veins accompanying the artery are known as venae comitantes. There is wide range of variations in the course of the veins and accordingly their course varies to some extent from man to man.

Classification of veins. Blood from the head, neck, superior extremity and the thorax drain into the right atrium of the heart through superior vena cava whereas the blood from the abdomen, pelvis and inferior extremity drain into the right atrium of the heart through inferior vena cava. Cardiac veins mostly drain into the right atrium of the heart through the coronary sinus, a few of them opening directly into the right atrium. The pulmonary veins drain their blood into the left

atrium of the heart. Thus the veins can be divided into two main groups, (*a*) those draining their blood into the right atrium, and (*b*) the pulmonary veins which drain into the left atrium. The veins which drain their blood into the right atrium are called *systemic veins*. Systemic veins can further be sub-divided regionally such as veins of the head and neck, superior extremity, thorax, abdomen, pelvis and inferior extremity and cardiac veins which form a group by themselves. According to size, veins are also divided into *large veins*, *medium veins* and *small veins* (venule).

Besides the veins of the systemic and the pulmonary circulation, the veins draining the abdominal portions of the gastro-intestinal tract together with the spleen and the pancreas have some special features peculiar to them, *although*, they drain ultimately into the systemic veins. These veins (veins draining the abdominal portions of the gastro-intestinal tract together with the spleen and the pancreas) are known as *portal system of veins*.

Special features of portal system of veins. They begin as veins and ultimately drain into a large single vein, the *portal vein*, which ends like an artery. The terminal venous capillary joins with a terminal capillary from the hepatic artery to form an arterio-venous common channel, the *hepatic sinusoid*, the blood from which drains ultimately into the hepatic veins which empty their content into the inferior vena cava (systemic vein). The blood from the portal system *feeds the liver* to provide it with various raw materials for elaboration of various essential substances for the body. The portal system of veins *have no valves* and they *carry deoxygenated blood containing nutritive materials from the gastro-intestinal tract.*

Besides the portal system of veins, which forms a venous territory under the systemic veins, there are veins in association with the vertebral column and these veins are collectively called *vertebral venous system*.

Histological structure of veins. Histologically the veins resemble the arteries in structure but here the coats are much thinner and are less well-formed. The large and medium veins, veins of the uterus (particularly during pregnancy), deep veins of the penis and the pulmonary veins have well defined muscular coat whereas the *veins of the sinuses of dura mater, veins of the bone marrow, veins of the brain and the spinal cord, the retinal veins and the venules in general*, have no muscular coat at all. Moreover, except the cerebral veins, the portal vein and the veins of the bone marrow, all the veins are provided internally with valves which are formed by the reduplication of the endothelial lining. In between the reduplicated liniogs the valves contain some elastic and collagen fibres.

Mechanism of venous circulation. The mechanism of venous circulation, that is, the means by which the blood from the different parts of the body is returned to the heart by the veins, involves a series of factors which act together in orderly sequence. The following forces work in the mechanism of venous circulation:

(1) *Squeezing action.* (*a*) The venous wall being thinner, the veins that pass through the muscles are squeezed during muscular action towards the heart. (*b*) During inspiration, with the descent of the diaphragm muscle, the intra-abdominal pressure rises which also has a squeezing effect on the intra-abdominal veins.

(2) *Intrathoracic suction action.* During inspiration the negative pressure within the pleural cavity increases which exerts a suction action on the great veins.

(3) *The venous valves.* Intraluminal valves effectively aid the venous circulation in that, once a column of blood passes ahead of the valve it cannot fall back.

(4) *Force of gravity.* The force of gravity plays a part in venous return when the veins come to lie in position higher than the heart. Normally the venous flow in the head and the neck are influenced (aiding venous return) by the gravity. Similarly the veins of the limbs being at a lower level than the heart, gravity hinders venous return which is counter-acted by other factors (intraluminal valves and squeezing action).

(5) *Driving force*. The intra-capillary pressure is higher than the intravenous pressure which exerts a driving force on the column of blood from the capillaries to the veins.

(6) *Volume of blood*. The volume of blood must be sufficient to maintain a steady circulation. With the increase of blood volume the venous return increases and with the decrease it decreases.

(7) *Other factors*. Factors which constrict the veins increase venous flow whereas those dilate them decrease venous flow. Like the arteries, constriction and dilatation of veins are under the control of vasomotor nerves and chemical and physical agencies.

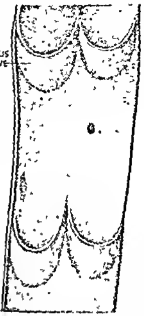


Fig. 588. The interior of a vein showing the valves.

Nerve supply of the blood vessels. Both arteries and veins are supplied by motor and sensory nerves. The motor nerves supplying the blood vessels are called *vasomotor* nerves which are derived from the autonomic nervous system (sympathetic fibres mostly and a few parasympathetic). The vasomotor nerves may be *vasoconstrictor*—that which constricts the blood vessels—or *vasodilator*—that which dilates the blood vessels. The sensory nerves of the blood vessels may be called *vasosensory* nerves which may be either *general* or *special*. The general vasosensory nerves are mostly concerned in carrying pain sensation. The special sensory nerves are distributed to the great vessels of the heart and are concerned in co-ordinating heart's action.

Although the nerves supplying the blood vessels are vasomotor and vasosensory, yet their functions are not always clearly understood in all cases. Thus the action of vasomotor nerves is not found to be so well manifested in cases of larger arteries and capillaries as it is found in cases of arterioles and smaller arteries. Similarly, not all the vasosensory nerves are of the same type with similar functions. The great vessels of the heart as well as the carotid sinus have special sensory mechanism to subserve special functions in co-ordinating heart's action. The following is a brief outline of the sensory nerves of the great vessels of the heart and the carotid sinus:

The sensory or afferent nerves supplying great vessels are of three types while those supplying the region of the carotid sinus are of two types—(*a*) those supplying the carotid sinus proper and (*b*) those supplying the carotid body.

Afferent or sensory nerves of the great vessels of the heart. (1) *Aortic nerve*. The aortic nerve terminates in special end-organs which are distributed to the tunica adventitia of the arch of the aorta and the roots of the great vessels that arise from it. Each nerve filament is a medullated fibre which winds spirally round the vessels in between the fibrous lamellae of the tunica adventitia and ends in an expanded extremity. The aortic nerve ascends along the fibres of the vagus nerve and ends centrally in the lower part of the medulla oblongata. The aortic nerve terminals react with the pressure changes within the arch of the aorta and the roots of the great vessels that arise from it and reflexly co-ordinates the heart's action through the centre in the medulla. With the rise in pressure, there is reflex vasodilation, fall of blood pressure and slowing of the heart beat; similarly with fall of pressure, there is vasoconstriction, rise in B.P. and increased frequency of heart beat reflexly. A *chemo-receptor* is also known to be present in some area on the walls of the aortic arch and is known as *aortic body*, or *glomus aorticum*. Functionally these chemo-receptors work in the same way as the chemo-receptors of the carotid body (*Vide* below).

(2) The intrapericardial portions of the superior and inferior venae cavae are also supplied by sensory nerves which also react with pressure changes within them. Thus when the intravenous pressure rises there is increased frequency of the heart

beat and with the fall in pressure there is slowing of the heart beat—(Brain-Bridge reflex). These fibres also pass along the vagus nerve.

(3) The third type of afferent nerves supplying heart are those which pass along the *middle* and *inferior cervical cardiac nerves* and *thoracic cardiac nerves.* These nerves are concerned with the painful sensations.

*The sinus nerve.** The afferent nerves supplying the carotid sinus are derived from the glossopharyngeal nerve and they end in termination similar to that of aortic nerves. Functionally they act in the same way as the aortic nerves and are concerned in co-ordinating heart's action in relation to pressure changes within the carotid sinus.

N B. The carotid sinus is a localised dilatation of the internal carotid artery just at its origin from the common carotid artery. Occasionally the position of the carotid sinus varies and it may occupy the terminal end of the common carotid artery and may extend to the origins of the external and internal carotid artery. The wall of the sinus is thinner than rest of the artery and is due to partial localised deficiency of muscle fibres in the tunica media of the vessel.

The nerve supply of the carotid body. The carotid body is a mass of epitheloid tissue situated at the bifurcation of the common carotid artery close to the carotid sinus. Within the carotid body are found numerous sinusoidal blood vessels. The glossopharyngeal nerve terminates within the body in exceedingly fine ramifications which come in close relation with the epitheloid cells and also reach beneath the sub-endothelial lining of the sinusoidal blood vessels. Functionally these nerve terminals act as *chemo-receptors**, that is, they re-act with some changes in the chemical composition of the blood. With rise in *p*H content of the blood or carbon-dioxide tension or with diminished oxygen content these nerve endings are stimulated and reflexly increase the frequency of the heart beat and respiration and raise the blood pressure. Similarly opposite results are found with decrease in *p*H and carbon-dioxide content of the blood and with increase in oxygen content.

The efferent or the vasomotor nerves. The efferent nerves are distributed to the walls of the heart (*Vide* nerve supply of the heart) as well as to the walls of the blood vessels. The vasomotor nerves of the blood vessels may be either vasoconstrictor or vasodilator. They may be derived either from the sympathetic or the parasympathetic or from both the components of the autonomic nervous system. The most of the vasomotor nerves are however sympathetic nerves.

The *parasympathetic vasomotor nerves are mostly vasodilator nerves.* The nervi erigentes from third and fourth sacral nerves dilate the penile vessels. They may be however vasoconstrictor as well. The coronary arteries are constricted with stimulation of parasympathetic. The *sympathetic vasomotor nerves are mostly vasoconstrictor nerves,* although, a few may act as vasodilators, as for example, the sympathetic nerves supplying the coronary and the pulmonary arteries are vasodilators.

The vasomotor nerves of the limb-vessels. The vasomotor nerves of the limbs are derived from the sympathetic nerves and are distributed to the arteries in two sets, *proximal* and *distal.* The proximal sets are derived directly from the sympathetic ganglia and are distributed to the walls of the main arteries as periarterial sheath which extends along the main artery of the limb for a variable distance. The distal sets are derived from the peripheral nerves which are distributed to the walls of the arteries.

The *sympathetic outflows (proximal and distal) for the upper limb arteries* are derived from the *second to the tenth thoracic segments of the spinal cord (preganglionic fibres)* and they end into the upper four thoracic, and inferior and middle cervical sympathetic ganglia from which the post-ganglionic fibres are distributed to the limb arteries in proximal and distal sets.

The *sympathetic outflows for the lower limb* are derived from the eleventh and twelfth thoracic, and the first and the second lumbar segments of the spinal cord and

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* For detailed study of the sinus nerve and the chemo-receptors of the carotid body the reader should consult a text book of Physiology on the subject.

are distributed along with the same segmental nerves (11th, 12th thoracic and 1st, 2nd lumbar nerves). These terminate by relays in the fourth lumbar to the third sacral ganglia from where post-ganglionic fibres are derived and are distributed to the lower limb arteries in proximal and distal sets.

The *splanchnic arteries* are supplied by post-ganglionic fibres from the coeliac ganglia and their pre-ganglionic fibres are derived from fifth to 9th thoracic segments of the spinal cord.

The *cerebral blood vessels* are supplied by sympathetic nerves. The pre-ganglionic fibres arise from the first thoracic segment and the post-ganglionic fibres arise from the inferior and the superior cervical sympathetic ganglia and run along with the internal carotid and the vertebral arteries.

Development of blood vessels. All the blood vessels are of mesodermal origin and are developed by growth and differentiation of the mesenchymal cells or the primitive connective tissue cells. The essential feature in the development of blood vessels is the formation of vascular endothelium which appears almost simultaneously in the area vasculosa of the yolk sac, in the body stalk and in the chorion and subsequently, within the embryo (from the intra-embryonic mesoderm); later on, communication is established between the extra-embryonic vascular endothelium and the intra-embryonic vascular endothelium and a closed system of endothelial blood vessels is formed and with the formation of the latter the circulation is established.

Formation of vascular endothelium. The vascular endothelium begins as endothelial capillaries and is formed by differentiation of the mesenchymal cells. In the region of the formation of future endothelial capillaries, the mesenchymal cells are arranged in isolated clumps known as the *angioblasts*. The angioblasts send out solid outgrowths known as *angioblastic cords* which interlace with one another. Later on, the central cells of the angioblastic cords further proliferate and there is accumulation of fluid (plasma) within the cords. As a result of this, the peripheral cells of the cords become flattened and they tend to be separated from the central ones by the accumulated fluid plasma inside the angioblastic cords. Then the angioblastic cords become canalised in which the peripheral flattened cells form the endothelial lining and the central cells are arranged in clumps to form 'blood islands' which are still attached to the endothelial lining. With the further accumulation of fluid plasma the 'blood islands' become detatched from the inner wall of the endothelial lining and later on, red blood corpuscles are formed by further differentiation of the cells of 'blood islands'.

Thus it is evident that all arteries either small or large begin as endothelial capillaries and later on, other elements of the arteries, that is, the muscular and fibrous tissue elements are added to them from the surrounding mesenchymal cells. It is also known that once the vascular capillaries are developed no new capillaries are formed independently but their formation may occur by a process of budding from the endothelial cells of the existing capillaries.

The earliest formed vascular capillaries are arranged in extensive networks, and with the growth and development of the embryo, some of them are either absorbed or are amulgamated together to form larger vessels in definite patterns and ultimately, according to the needs, definite arteries are formed to subserve the function of the particular parts.

Some clinical aspects of the blood vessels. *The pulse.* Some of the superficial arteries are seen to be pulsating while some others can easily be palpated. Clinically, the radial artery is felt just above the wrist and many a useful information are noted regarding the heart's condition and about the condition of the arterial wall in general. The feeling of the radial artery by the fingers is popularly known as 'the feeling of the pulse' (radial). It is the regular, pulsatile expansion of the arterial wall which is synchronised with the systole of the heart and can be felt with the finger. The normal resting pulse rate in the adult is between 70 and 80 beats in a minute and it varies with age, sex and with exercise and rest.

The blood pressure. It is the lateral pressure exerted by the column of blood on the walls of an artery and is measured by an instrument known as the sphygmomanometer. During systole, the ventricles of the heart contract to force out some (5 OZ) additional quantity of blood into the arterial system which reciprocally exerts additional pressure on the walls of an artery and the maximum pressure on the arterial walls during the systole of the heart is known as the *systolic pressure* and the minimum pressure during the diastole of the heart is known as the *diastolic pressure*. The normal systolic pressure ranges from 110 to 140 mm. Hg. and the diastolic pressure from 70 to 90 mm. Hg. in the adult. However it varies with age, sex, rest, with exercise and in diseases.

The retinoscopy. The retinal blood vessels can be seen brilliantly in the living body with the aid of an instrument known as the ophthalmoscope. Such observation gives us an opportunity to look into the vessels directly, and with little experience, it may be possible not only to know about the local condition but also to have an estimate about the conditions of the arteries in general.

Angiography. It is a method of investigation in which a radio-opaque substance is injected into the blood vessels and subsequently a radiogram is taken. This gives a picture about the pattern, field of distribution, the patency of the injected vessels and about the routes of circulation of the injected vessels.

N.B. It is believed that the white blood corpuscles are formed outside the capillary endothelium from the mesenchymal cells and that they crawl their way through the walls of the vessels to get into their lumen.

THE PERICARDIUM

The pericardium forms a conical fibro-serous, membranous bag which encloses the heart with the great vessels contained within the middle mediastinum, and separates them from the anterior and the posterior chest-walls by the overlapping lungs in front, and by the structures of the posterior mediastinum behind. It lies opposite the body of the sternum together with the second, third, fourth and the fifth costal cartilages attached to it and extends from the body of the fifth to that of the eighth thoracic vertebra.

Structurally, it consists of outer fibrous and inner serous layers.

The fibrous pericardium forms a strong, dense membrane which surrounds the heart and fixes it partially with the back of the sternum and with the great vessels and acts as a 'sling' for the heart. It also limits its sudden overdistension.

Attachments. Superiorly, it is fused with the walls of the great vessels and is continuous with the pretracheal layer of the deep cervical fascia. *Inferiorly,* it is attached to the central tendon of the diaphragm and for a small extent, to the musculature of the same. Its attachment to the muscular part of the diaphragm extends more on the left side than that on the right. *Anteriorly,* the fibrous pericardium is attached to the back of the sternum by two ligamentous bands known as the superior and the inferior sternopericardial ligaments. The superior sternopericardial ligament is attached to the back of the upper part of the body of the sternum whereas the inferior sternopericardial ligament is attached to the back of the lower part of the body of the sternum. The fibrous pericardium invests all the great vessels connected to the heart except the inferior vena cava.

The *serous pericardium* consists of parietal and visceral layers which are continuous with each other. The parietal layer of the serous pericardium lines the inner surfaces of the fibrous pericardium and then is reflected on to the great vessels and to the surfaces of the heart to form the visceral pericardium which is also known as the epicardium. In between the parietal and the visceral layers, the serous pericardium encloses a closed cavity known as the pericardial cavity.

The *pericardial cavity* is a closed sac formed between the reflections of the visceral and the parietal layers of the serous pericardium. Normally the pericardial cavity contains a glairy fluid formed by the serous pericardium. The amount of the

is just sufficient to form a thin film over the opposing surfaces of the viscer
parietal layers of the serous pericardium and this acts as a perfect lubricant
ires free movement of the heart.

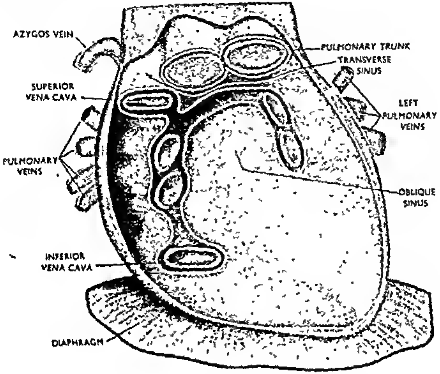


Fig. 589. The sinuses of the pericardium.

The pericardial cavity consists of a main portion and two recesses, the transverse sinus and the oblique sinus. The *transverse sinus* is that part of the pericardial cavity which intervenes between the visceral layer of the serous pericaridium enclosing the aorta and the pulmonary trunk in front, and the visceral pericardium investing the atria, behind, in other words, it is bounded in front by the pulmonary trunk and the ascending aorta and behind by both the atria.

N.B. In early embryonic life the primitive heart forms a tube which is invaginated into the serous pericardium and is suspended by a mesentery. Later on, the primitive heart tube is bent on itself to form an U-shaped tube which is still suspended from the posterior wall by the mesentery. Subsequently, the mesentery between the two limbs of the U-shaped tube disappears making a space between them which communicates the two sides of the primitive pericardial cavity in between and across the two limbs of the U-shaped tube. This space in future life forms the transverse sinus of the pericardium.

The *oblique sinus* of the pericardium is a cul-de-sac bounded by the visceral layer of the serous pericardium enclosing the right and the left pairs of the pulmonary veins at the sides, the base of the heart in front, and by the parietal layer of the serous pericardium covering the fibrous pericardium posteriorly.

A triangular fold of serous pericardium extending between the left pulmonary artery and the superior left pulmonary vein is known as the *fold of the left vena cava* which encloses a fibrous band within it known as the *ligament of the left vena cava.*

N.B. During early embryonic life the left anterior cardinal vein together with the left posterior cardinal vein opens into the sinus venosus by the duct of Cuvier. Later on, a transverse vein connects the two anterior cardinal veins together which forms the future left brachiocephalic (innominate) vein. The portion of the left anterior cardinal vein caudal to the transverse venous channel subsequently atrophies and its fibrous remains forms the ligament of the left vena cava in later life. The anterior cardinal vein, in early prenatal life, is called the left superior vena cava.

Relations of the Pericardium. Anteriorly, opposite the left-half of the lower part of the body of the sternum and the adjoining inner ends of the fourth, fifth and the

sixth costal cartilages together with the fourth and fifth intercostal spaces, the heart with the pericardium is directly related to the back of the anterior chest-wall (bare area of the heart). In the rest of its extent it is overlapped anteriorly by the anterior margins of the lungs and the pleura which separate it from the back of the anterior chest-wall. During the growing period until puberty the lower end of the thymus gland forms an additional anterior relation superiorly and intervenes between the lungs and pleurae in front and the pericardium posteriorly. The fibrous pericardium is connected anteriorly with the back of the sternum by the superior and the inferior sternopericardial ligaments. On either side it is intimately related to the mediastinal pleura which separates it from the mediastinal surface of the corresponding lung. The phrenic nerve and the pericardiaco-phrenic vessels descend downwards in between it and the mediastinal pleura. Posteriorly, it is related to the left bronchus, the oesophagus with the oesophageal plexus of nerves, the descending thoracic aorta and the posterior part of the mediastinal surface of the lungs which separate it from the fifth to the eighth thoracic vertebrae. Inferiorly, the fibrous pericardium is adherent to the central tendon of the diaphragm and is separated from the liver and the fundus of the stomach by the diaphragm.

Vascular supply. The fibrous pericardium and the parietal layer of the serous pericardium are supplied by the pericardial branches of the descending thoracic aorta and the pericardial and the pericardiacophrenic branches of the internal mammary artery. The visceral pericardium is supplied by branches from the coronary arteries.

The veins are corresponding to the arteries.

Nerve supply. The parietal pericardium is supplied by the phrenic nerve whereas the visceral pericardium is supplied by the vagus and the sympathetics.

Lymphatics. The lymphatics draining the parietal pericardium drain into the anterior, posterior and superior mediastinal groups of lymph glands.

Development. The most of the fibrous pericardium and the parietal layer of the serous pericardium develop from the somatopleuric mesoderm of the primitive pericardial cavity whereas the visceral pericardium or the epicardium develops from the splanchnopleuric mesoderm and is differentiated from the superficial layer of the myoepicardial mantle. The portion of the pericardium adherent to the diaphragm is derived from the cranial part of the septum transversum.

The transverse sinus of the pericardium develops as a result of breakdown of the mesocardium of the primitive heart. The oblique sinus develops as a result of absorption of the sinus venosus in the walls of the developing atria and the re-adjustment of the veins into it.

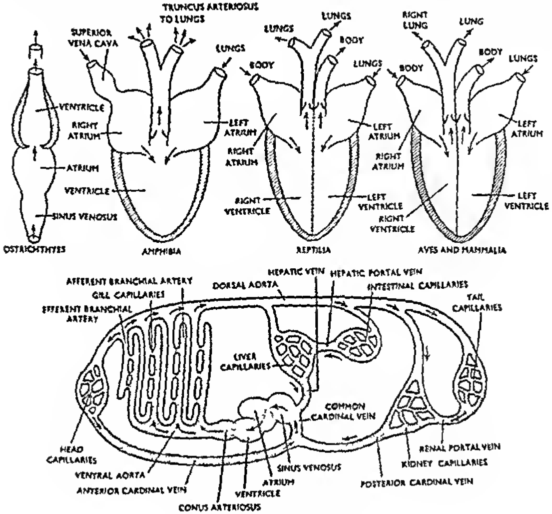
THE HEART

The human heart is a hollow muscular organ, completely divided into a right and a left half, each of which consists of a receiving chamber or a atrium, which receives blood from the veins, and a delivering chamber or a ventricle which propels the blood into the arteries.

The evolution of heart. In the simpler forms of vertebrates, such as in the fishes (osteichthyes) the heart consists of a single muscular ventricle, a single atrium and a *sinus venosus*. Blood flows into the sinus venosus through the hepatic and the common cardinal veins and from there it passes into the single atrium; the atrium then contracts and forces the blood into the ventricle; the ventricle then contracts and forces out the blood through the conus arteriosus into the gill arches. After being oxygenated in the gill arches the blood flows into the dorsal aorta for distribution into the tissues. *Thus the primitive heart is only a respiratory pump which forces blood into the gill arches.*

In the Amphibia there are two atria, the right one for receiving venous blood from the body and the left one for receiving oxygenated blood from the lungs. The

blood from both the atria passes to a single ventricle where, although there is scope for mixing, there is very little mixing between the oxygenated and the venous blood. The ventricle contracts to force out the blood (venous) first into the pulmocutaneous arches and then (oxygenated blood) in the carotid *and systemic circulation*.



the circulatory system in a fish

Fig. 590. The heart in evolution.

In most of the reptiles the heart consists of two atria and a ventricle which is partly divided into two, right and left. When the ventricle contracts, the venous blood passes out into the lungs via the pulmonary artery and into the dorsal aorta via the left aorta, and the oxygenated blood into the dorsal aorta through the right aortic arch. Thus in the dorsal aorta there is mixing up of the oxygenated and the venous blood.

In some of the reptiles (crocodiles), birds and mammals the heart forms a four-chambered organ in which the ventricles are completely separated from each other and the venous blood from the right atrium passes to the right ventricle whereas the oxygenated blood from the left atrium passes to the left ventricle. Thus the venous and oxygenated blood are kept apart completely.

Shape and form. In a formalin-hardened body the heart resembles like a flattened cone having a base, an apex and three surfaces, sternocostal, diaphragmatic and left. However, depending on the general physique and the form of the chest, the shape and form of the heart vary considerably.

The living heart also varies considerably in its shape in different individuals, during inspiration and expiration and in different forms of the chest. In the tall and thin persons, in other words, in asthenic or leptosomatic individuals where the chest-walls are long and narrow, the heart is said to be long. In the short, stout individuals (hypersthenic) where chest-walls are short and wide, the heart is said to be transverse. In the sthenic or athletic types, as in the average individuals, the heart is neither long nor transverse but it assumes a oblique lie.

During deep inspiration, with the descent of the diaphragm, the heart becomes elongated with narrowing of its transverse diameter. During deep expiration its vertical diameter becomes shortened and it assumes a transverse form.

Size and weight. The size and weight of the heart gradually increase with age till the advanced period of life. In the adult European, it measures about 8-9 cm. transversely at its widest part, about 6 cm. anteroposteriorly, and its vertical length from base to the apex, measures about 12 cm. Its weight in the adult male varies between 280 and 340 grammes and in the adult female between 230 and 280 grammes.

External features. Of the four chambers of the heart two are ventricles, right and left, which occupy the sterno-costal, left and inferior surfaces of the heart and two

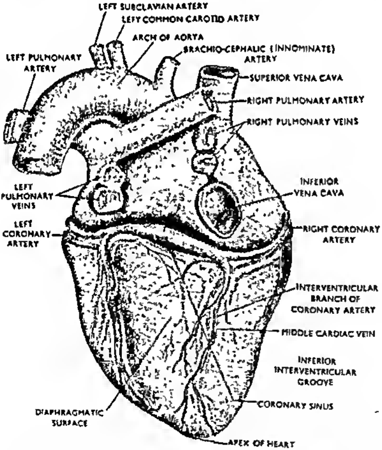


Fig. 591. The heart viewed from behind. With the kind permission from Lederle Laboratories—drawn by Mr. Paul peck.

are atria, right and left, which occupy the basal aspect of the heart. The two ventricles are separated from each other by two longitudinal grooves, one on the sternocostal surface called the anterior interventricular groove containing the inter-

ventricular branch of the left coronary artery, and one on the inferior surface called the inferior interventricular groove. The two ventricles are separated from the two atria by the atrioventricular groove which is situated on the posterior aspect of the heart and contains the coronary sinus. This groove is deficient anteriorly by the presence of the pulmonary trunk. The atria are separated from each other by a vertical groove, the interatrial groove, which is usually very ill-defined and is not easily detectable. A conical pouch-like projection from each atrium, which embraces the great vessels of the heart, is called the corresponding auricle of the heart *i.e.*, from the right atrium, the right auricle and from the left atrium, the left auricle.

The Base of the Heart. The base of the heart is more or less quadrilateral in shape. It is formed mainly by the left atrium and partly by the right atrium of the heart. It lies opposite to the fifth, the sixth, the seventh, and the eighth thoracic

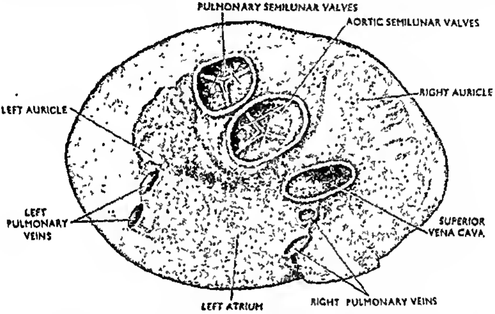


Fig. 592. The base of the heart seen from above. From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

vertebrae and is separated from them by the pericardium, the oesophagus, the descending thoracic aorta, the vagus nerves, azygos and hemiazygos veins, the thoracic duct and the right pulmonary veins.

It is bounded above by the bifurcation of the pulmonary artery, below by the inferior part of the atrioventricular groove containing the coronary sinus. On the right side, at the upper and lower angles, are the openings of the superior and inferior venae cavae, and in between the two, it is bounded by that portion of the right atrium which extends from the right margin of the opening of the superior vena cava to the right margin of the opening of the inferior vena cava. On the left side, it is bounded by the rounded left border of the left atrium. Four pulmonary veins,—two right and two left, open into the corresponding sides of the left atrium and they are arranged in pairs being situated one above the other. The portion of the left atrium in between the right and left pairs of veins forms the anterior surface of the oblique sinus of the pericardium. An interatrial groove, though very ill-defined in human subject, may mark its presence in this part of the heart.

Apex of the Heart. The apex of the heart is formed only by the left ventricle of the heart and forms a conical projection at the junction of the left and the inferior margins of the heart. It is directed downwards, forwards and to the left and corresponds to a point on the left fifth intercostal space about $3\frac{1}{2}$ inches from the mid-sternal line. It is separated from the chest-wall by the pericardium and the overlapping left lung and pleura.

Sternocostal Surface. The sternocostal surface of the heart is formed by both the ventricles and the atria and is directed upwards, forwards and to the left. It is incompletely divided into upper and lower sections by the upper part of the atrioventricular groove. The upper section is formed by the atria and is mostly hidden from the view by the ascending aorta and the pulmonary trunk. The two auricles of the atria, one from each atrium, curve medially so as to embrace the roots of the great vessels (ascending aorta and pulmonary trunk) from either side. The

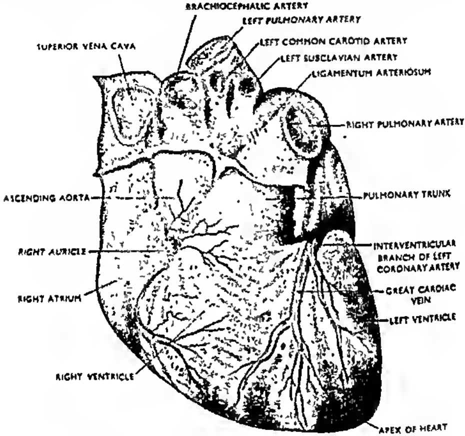


Fig. 593. The sternocostal surface of the heart.
With the kind permission from Lederle Laboratories—drawn by Mr. Paul Peck.

lower section of the sternocostal surface is formed by the ventricles. About tw thirds of it are formed by the right ventricle and one-third by the left ventricle. Th line of separation between the two ventricles is marked by the anterior interventricul groove which contains the interventricular branch of the left coronary artery an the great cardiac vein.

Relations. The upper section of the sternocostal surface is separated fro the sternum by the ascending aorta, the pulmonary trunk, the pericardium ar by overlapping margins of the lungs and pleura. The lower or the ventricular sectic of the sternocostal surface is separated from the sternum and the medial ends of t costal cartilages of the fourth, fifth and the sixth ribs of both sides, but for a great extent from the corresponding cartilages of the left side, by the pericardium and t overlapping lungs and pleura except opposite the cardiac notch of the left lung whe the pericardium with the heart comes into direct relation with the chest-wall.

Diaphragmatic surface. It is formed by the inferior surfaces of the right a left ventricles and rests upon the central part of the diaphragm being separated l the pericardium. The inferior interventricular groove traverses this surface a lodges the branches of the right coronary artery.

Left surface. It is formed mainly by left ventricle and partly by the left atrium and the left auricle. It is traversed by the left coronary artery and is related to the mediastinal surface of the left lung being separated by the pericardium and the left phrenic nerve and the pericardiaco-phrenic vessels.

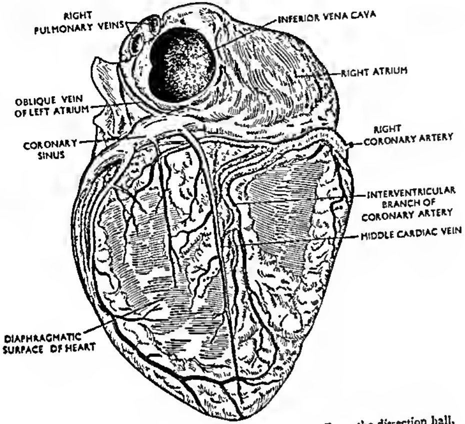


Fig. 594. The heart showing the diaphragmatic surface. From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

Infundibulum. The infundibulum of the heart is a pouch-like dilatation of the walls of the right ventricle opposite the origin of the pulmonary trunk. The character of this part of the right ventricle is that it presents a smooth surface within which is quite different from the other parts of the cavity of the right ventricle where the inner walls present irregular elevations.

THE CHAMBERS OF THE HEART: THE RIGHT ATRIUM

The right atrium of the heart is cubodial in shape and is situated behind and above the right ventricle of the heart. It is seen to form the right border, a small part of the sternocostal surface and a part of the base of the heart. A small conical projection, the auricle of the right atrium, projects forwards and medially on the right side of the ascending aorta to reach the side of the pulmonary trunk. The superior vena cava opens into the upper and posterior part and inferior vena cava opens into the lower and posterior part of the right atrium. A faint groove, the sulcus terminalis, extends from the anterior aspect of the superior vena cava to the front of the inferior vena cava and it corresponds to the crista terminalis within the interior of the atrium.

Relations. *Anteriorly,* it is related to the anterior part of the mediastinal surface of the right lung from which it is separated by pleura, and pericardium. *Laterally,* it is related to the mediastinal surface of the right lung in front of its hilum and is separated from it by the pericardium, the phrenic nerve, the pericardiaco-phrenic

vessels and the pleura. *Posteriorly and to the left* it is separated from the left atrium by the inter-atrial septum; *posteriorly and to the right* it is related to the right pulmonary veins. *Medially*, it is related to the ascending aorta and the pulmonary trunk.

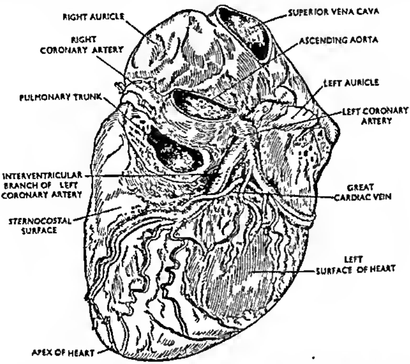


Fig. 595. The heart showing the left surface. From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

The interior of the right atrium. *The walls.* On examining the internal surface of the right atrium, the posterior portion is seen to be smooth, while the anterior portion is raised into numerous parallel muscular ridges. Developmentally the posterior smooth portion represents the right horn of the sinus venosus which merges into wall of the primitive atrium. The anterior portion, characterised by ridged-walls, represents the primitive atrium in the adult heart. Thus, morphologically, the interior of the right atrium can be divisible into *sinus venerum* featured by smoothness and occupying the posterior aspect of the adult heart and into *atrium proper* featured by ridged-walls and occupying the anterior portion. The openings *of the superior and inferior venae cavae, coronary sinus and venae cordis minimae* are found in the sinus venerum.

A smooth muscular ridge extends from the upper end of the inter-atrial septum and crossing in front of the opening of the superior vena cava it descends on its right side to the right side of the inferior vena cava and is known as *crista terminalis* which corresponds to the sulcus terminalis on the external surface. A series of parallel ridges extend forwards on the right wall from the crista terminalis which are called *musculae pectinati.* They are also found within the auricle.

The orifices. The *opening of the superior vena cava* is situated at the upper and posterior part of the right atrium—unguarded by valves. The *inferior vena cava opens* into the lower and back part of the right atrium and its termination is guarded by a rudimentary valve known as the valve of the inferior vena cava. The *atrioventricular or tricuspid orifice* is a large oval opening situated at the lower and anterior part of the atrium and communicates the right atrium with the right ventricle. The *opening of the coronary sinus* lies between the tricuspid orifice and the opening of the inferior vena cava. It is guarded by a rudimentary valve known as the coronary

valve. *Foramina venarum minimarum* are the openings of the venae cordis minimae on the wall of the heart. They are chiefly found on the septal wall of the heart.

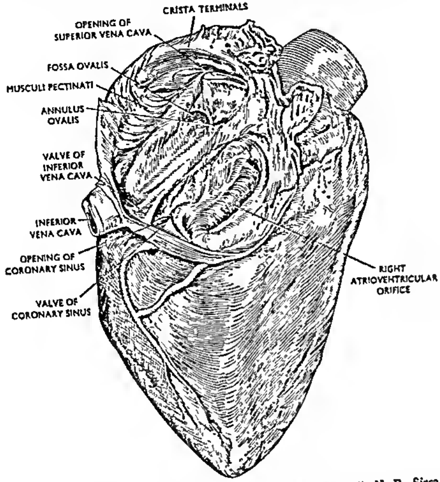


Fig. 596. The interior of the right atrium. From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

The septum. If the septum between the two atria is examined, an oval depression will be seen a short distance above the orifice of the inferior vena cava. This depression is known as the *fossa ovalis*. It indicates the position of the foramen ovale of the foetal heart. It is surrounded above and in front by a ridge, which is continuous with the valve of the inferior vena cava, the *limbus fossae ovalis* (*annulus ovalis*). The limbus fossae ovalis represents the free edge of the septum secundum of the developing heart in the embryonic life. An elevation, the *intervenous tubercle*, can sometimes be seen on the inter-atrial septum between the orifices of the superior and inferior venae cavae posterior to the upper part of the fossa ovalis.

Interior of the right ventricle. The interior of the right ventricle is divisible into upper out-flowing part, the *infundibulum*, and into lower in-flowing part by the supraventricular crest and when exposed the following features will be found:

(1) Right atrioventricular orifice.
(2) Pulmonary orifice.
(3) Tricuspid valves.
(4) Pulmonary valves.
(5) Trabeculae carneae.
(6) Septomarginal trabecula (Moderator band).
(7) Supraventricular crest (Infundibulo-ventricular crest).

Right atrioventricular orifice. It is larger than the left atrioventricular orifice and is situated at the base of the ventricle and forms the orifice of communication between the right atrium and the right ventricle. It is an oval or a round opening measuring about 12 or 13 cm. in its circumference and roughly it admits the tips of three or four fingers. Its opening is surrounded by a fibrous ring which is lined by the endocardium. It is guarded by the tricuspid valve.

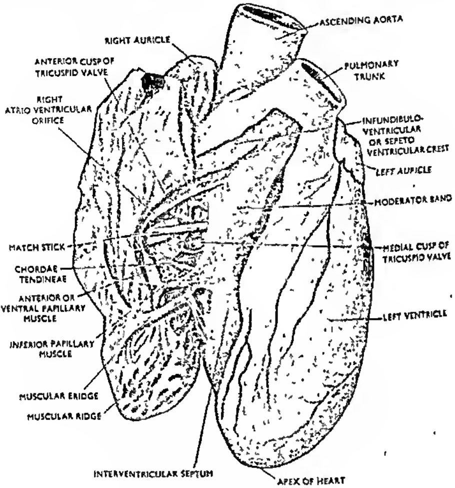


Fig. 597. The interior of the right ventricle.
From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

Pulmonary orifice. It is a rounded opening situated at the summit of the infundibulum and marks the commencement of the pulmonary trunk. It measures about 3 cm. in diameter and is guarded by the pulmonary semilunar valves.

Pulmonary semilunar valves. The pulmonary semilunar valves guard the pulmonary orifice and consist of three semilunar cusps, two anterior and one posterior. Each cusp presents an attached border and a free border. The attached border forms a semilunar attachment on the inner wall of the pulmonary trunk and directed downwards towards the ventricular cavity. Its free border is directed upwards towards the lumen of the pulmonary trunk. It presents a *nodule*, formed by the thickening of the underlying fibrous tissue, in its centre, and the thin margin extending from it to the wall of the arterial trunk is known as *lunula*. The pulmonary trunk presents a localised dilatation opposite each cusp known as the *sinus*. Each valve is formed by the reduplication of the endothelial lining together with a layer

Anomalies. As already stated there may be complete absence of the external carotid artery or occasionally it may arise directly from the arch of the aorta.

Superior thyroid artery. It arises from the front of the external carotid artery immediately below the greater cornu of the hyoid bone. At first it lies under cover of the anterior border of the sternocleidomastoid muscle and then it becomes superficial being covered only by the skin, superficial fascia, platysma and the deep fascia and then again it becomes deep as it descends downwards beneath the omohyoid (superior belly), sternohyoid and sternothyroid muscles and finally reaching the upper pole of the thyroid gland it breaks up into two terminal branches *anterior* and *posterior*. Medially it is related to the inferior constrictor muscle of the pharynx and the external laryngeal nerve.

The *anterior branch* runs along the medial border of the upper pole of the thyroid gland and supplies the superficial surface of the thyroid and provides an anastomosing branch which runs along the upper border of the isthmus and ends by anastomosing with the fellow of the opposite side.

The *posterior branch* runs along the posterior border of the gland and supplies the medial and the posterior surfaces and finally ends by anastomosing with the inferior thyroid artery.

Branches:

(1) Infrahyoid.
(2) Sternomastoid.
(3) Superior laryngeal.
(4) Cricothyroid.
(5) Terminal glandular.

Infrahyoid artery. This is a small artery arising from the superior thyroid artery and runs forwards along the lower border of the hyoid bone and ends by anastomosing with the fellow of its opposite side.

Sternomastoid. The sternomastoid branch of the superior thyroid artery runs downwards and laterally in front of the carotid sheath and soon enters into the sternomastoid muscle. This artery may arise from the external carotid artery.

Superior laryngeal. The superior laryngeal branch of the superior thyroid artery is larger than the preceding two arteries and runs upwards and medially behind thyrohyoid muscle and accompanying the internal laryngeal nerve it pierces the hyothyroid membrane and lies below the internal laryngeal nerve. It supplies the muscles, mucous membranes and glands of the larynx and ends by anastomosing with the fellow of its opposite side and also with the inferior laryngeal branch of the inferior thyroid artery.

Cricothyroid. It is a transverse branch from the superior thyroid artery and runs transversely across the upper border of the cricothyroid membrane and ends by anastomosing with the artery of the opposite side.

Terminal glandular. The terminal grandular branches are anterior and posterior and have been described with the main artery.

Lingual artery. It arises from the antero-medial part of the external carotid artery opposite the tip of the greater cornu of the hyoid bone in between the superior thyroid and the facial arteries. After a short course from its origin it lies deep to the hyoglossus muscle and finally leaving this muscle it ends in the tongue by anastomosing with the fellow of its opposite side. Thus the hyoglossus muscle divides the artery into three parts—first part, second part and the third part. The first part of the artery extends from its origin to the posterior border of the hyoglossus muscle, the second part lies deep to hyoglossus while the third part extends from the anterior border of the hyoglossus to the tip of the tongue.

First part of the lingual artery. The first part of the lingual artery lies in the carotid triangle and extends from its origin to the posterior border of the hyoglossus muscle; at first it runs upwards, forwards and medially and then forming a loop descends downwards to the greater cornu of the hyoid bone and reaches the posterior border

of the hyoglossus muscle; in this part of its course it is superficial, being covered only by the skin, superficial fascia, platysma and the deep fascia; it lies on the middle constrictor muscle of the pharynx. The loop which is the characteristic of the artery is crossed by the hypoglossal nerve.

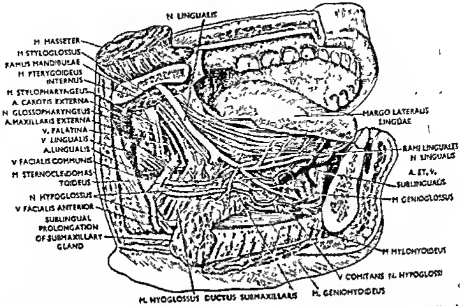


Fig 604. A dissection of the infratemporal region. With the kind permission from: Callander's Surgical Anatomy 2nd edition 1939, W. B. Saunder's Company, Philadelphia and London.

Second part of the lingual artery. The second part of the lingual artery lies deep to the hyoglossus muscle. In this part of its course it runs along the upper border of the hyoid bone and is covered by the hyoglossus, the tendon of the digastric, stylohyoid and the posterior part of the mylohyoid muscle and the lower part of the submandibular gland. It is separated from the hypoglossal nerve and its venae commitans by the hyoglossus muscle. It lies on the middle constrictor muscle of the pharynx.

Third part of the lingual artery. The third part of the lingual artery extends from the anterior border of the hyoglossus muscle to the tip of the tongue. At the anterior border of the hyoglossus muscle the lingual artery gives out its sublingual branch and then is continued to the undersurface of the tongue as the *arteria profunda linguae.* At first it ascends vertically upwards and then runs forwards to the undersurface of the tongue on the side of the frenulum and finally reaches the tip of the tongue where it ends by anastomosing with the fellow of its opposite side. In this part of its course it is accompanied by the lingual nerve, and the genioglossus muscle lies on its medial side. Laterally it is related to the longitudinalis linguae inferior and inferiorly is covered only by the mucous membrane of the tongue.

Branches:

(1) Suprahyoid.
(2) Rami dorsales linguae.
(3) Sublingual.
(4) Arteria profunda linguae.

Suprahyoid. It is a small branch which runs along the upper border of the hyoid bone and ends by anastomosing with the fellow of its opposite side.

Rami dorsales linguae. They are two or three small branches which arise from the lingual artery under cover of the hyoglossus muscle and ascend upwards on the dorsum of the tongue. They anastomose with the fellow of the opposite side and

fibrous tissue interposed between them. During contraction of the ventricle they are opposed against the inner wall of the arterial trunk and with cessation of the ventricular systole their pockets are filled in with blood and the three cusps are approximated to one another so as to completely obliterate the orifice.

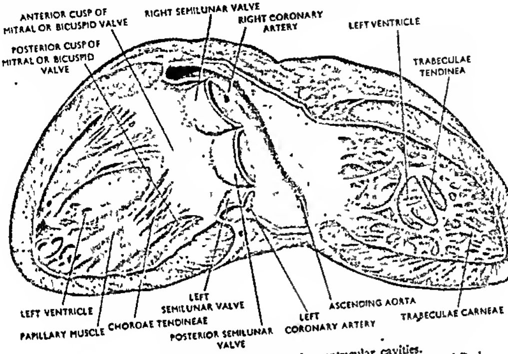


Fig. 598. The heart showing its ventricular cavities.
With the kind permission from Lederle Laboratories—drawn by Mr. Paul Peck.

The tricuspid valves. The tricuspid valves, as the name implies, consist of three cusps or valves, ventral (anterior), septal (medial) and dorsal (inferior). These three cusps by their close apposition guard the mouth of the right atrioventricular orifice and prevent the regurgitation of blood from the ventricle to the atrium during the contraction of the former.

The *ventral (anterior) cusp* is the largest of all and intervenes between the pulmonary and the right atrioventricular orifices.

The *septal (medial) cusp* lies in contact with the septal wall of the ventricle and the *dorsal (inferior) cusp* lies below and in between the ventral and septal cusps.

Each cusp is triangular in form with its apex directed towards the cavity of the ventricle. Their bases are attached to the fibrous ring surrounding the right atrioventricular orifice and their apices are attached to the wall of the ventricle by their thread-like processes called the *chorda tendineae*. Their central portion is thick and peripheral portion thin. Their atrial surfaces are smooth while their ventricular surfaces are rough and irregular. They are formed by the reduplication of the lining membrane of the cavity of the ventricle.

During the contraction of the ventricle they, by their closer apposition, prevent the regurgitation of blood from the ventricle to the atrium, while during the contraction of the atrium, they are widely separated from each other and each inclining to the different walls of the ventricular cavity.

Trabeculae carneae. The trabeculae carneae are round or irregular muscular elevations present throughout the cavity of both the ventricles except the infundibulum of the right ventricle where they are absent. They, in the left ventricle, are stouter and stronger and are forming denser interlacement than those of the right ventricle. Trabeculae carncae cousist of ridges, bridges and papillary mu

Ridges are simple muscular elevations on the walls of the ventricles while the *bridges* form the elevated muscular columns which are undermined.

Papillary muscles are the solid, conical muscular projections present in both the ventricles of the heart. Each is conical in shape with its *base* attached to the walls of the ventricle and its *apex* directed towards the ventricular cavity.

They are usually multiple in both the ventricles. Those in the left ventricle are stouter and stronger than those of the right.

Papillary muscles of the right ventricle. In the right ventricle they are two in number, ventral and dorsal. The *ventral (anterior) one* is attached to the septal wall of the ventricle and by its apex gives attachment to the chordae tendineae of the ventral and dorsal cusps of the tricuspid valve. The *dorsal (inferior) papillary muscle* of the right ventricle, by its base, is attached to the diaphragmatic wall and by its apex gives attachment to the chordae tendineae of the septal and dorsal cusps of the tricuspid valve.

The papillary muscles during the contraction of the ventricles pull the chordae tendineae of the respective valve and thereby prevent the invertion of the same.

Supraventricular crest (Infundibulo-ventricular crest). This is a smooth muscular ridge which stretches between the pulmonary and right ntrioventricular orifices and sub-divides the interior of the right ventricle into upper out-flowing part, the infundibulum, and the lower in-flowing part. In its course it passes downwards and to the right from the posterior wall of the infundibulum to the right atrioventricular orifice. It prevents the overdistention of the ventricle.

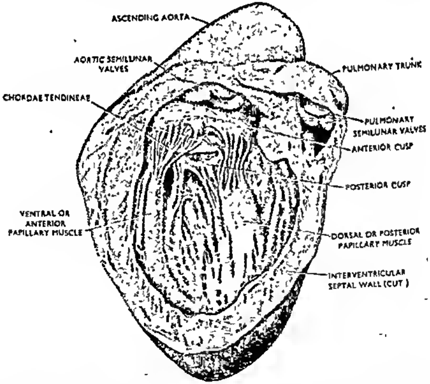


Fig. 599. The interior of the left ventricle. The interventricular septum together with a part of the left surface of the heart has been removed. From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

Septomarginal trabecula (Moderator band). This is a smooth muscular ridge present on the ventricular surface of the septal wall of the right ventricle. It extends

from the lower part of the infundibulum to the base of the anterior papillary muscle. It prevents the overdistention of the ventricle.

Interior of the left ventricle. The interior of the left ventricle presents the following features:

(1) Left atrioventricular orifice.
(2) Aortic orifice.
(3) Left atrioventricular or bicuspid or mitral valve.
(4) Aortic valves.
(5) Trabeculae carneae.
(6) Chordae tendineae.

Left atrioventricular orifice. The left atrioventricular orifice communicates the left atrium with the left ventricle and is situated below and to the left of the aortic orifice. It measures about 10 cm. in its circumference and usually admits the tips of two or three fingers. It is guarded by the bicuspid valve and its opening is surrounded by a fibrous ring like that of the right atrioventricular orifice.

Aortic orifice. The aortic orifice is situated in front and to the right of the left atrioventricular or mitral orifice. It is roughly circular in outline and measures about one inch in diameter. It is separated from the mitral orifice by the anterior cusp of the mitral valve. The portion of the left ventricle immediately below the aortic orifice is known as the *aortic vestibule* which has no muscular wall but is made up of fibrous tissue lined internally by the endocardium. The aortic orifice is guarded by the aortic semilunar valves.

Mitral or left atrioventricular or the bicuspid valve. It consists of two cusps, anterior and posterior. The *anterior cusp* is the larger of the two and is interposed between the aortic and the left atrioventricular orifices. The *posterior cusp* is situated posterior to and to the left of the aortic orifice. The mitral valves are thicker than the tricuspid valves and have the similar attachments and chordae tendineae like that of the latter. Each cusp is formed by the reduplication of the endocardium containing in between its two layers some fibrous tissues.

Aortic semilunar valves. The aortic semilunar valves have the same characteristics like those of the pulmonary semilunar valves and their arrangement is, *one anterior* and *two posterior cusps*. The aortic cusps are a bit thicker, larger and stronger than the pulmonary cusps and the nodules are more prominent and thick. The dilatation of the aortic wall opposite each cusp is known as the *aortic sinus*. The *right coronary artery* arises from the *anterior aortic sinus* while the *left coronony artery* arises from the *left posterior aortic sinus*.

Trabeculae carneae and chordae tendineae. They have similar features like those of the right ventricle except that they are more prominent, thick and strong than those in the right ventricle.

Papillary muscles of the left ventricle. They may be broken into two or three small projections. In the left ventricle papillary muscles are two in number and according to their situation one is *superior*, attached to the sterno-costal wall of the heart and one is *inferior*, attached to the diaphragmatic wall of the heart. By their apices they give attachment to the chordae tendineae of the bicuspid valve.

Interior of the left atrium. The interior of the left atrium presents the following features:

Openings of the pulmonary veins. The four pulmonary veins, arranged in right and left pairs open into its upper part.

Left atrioventricular orifice. It has already been described.

Foramina venarum minimarum. Same as those in the right atrium.

Musculi pectinati. They are few in number and are present within the interior of the auricle.

Ventricular (Interventricular) septum. It is a fibro-muscular septum which intervenes between the two ventricles and externally its margins correspond to the anterior and inferior interventricular grooves. It is almost entirely muscular except superiorly where over a small extent it is fibrous and is known as the *membranous portion of the ventricular septum.* Its right surface is convex and is directed to the cavity of the right ventricle. The membranous portion of this surface is divided into anterior and posterior parts by the attachment of the septal cusp of the tricuspid valve. The anterior part separates the two ventricles from each other while its posterior part separates the aortic vestibule from the right atrium. Superiorly, it extends upto the tendon of the infundibulum. The membranous ventricular septum is pierced by the left branch of the bundle of His.

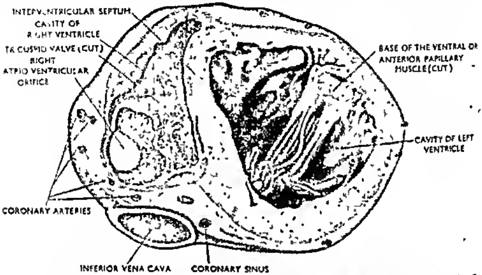


Fig 600. A transverse section of the heart across its ventricles. From the dissection hall, N. R. Sarkar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

Structure of the heart. The heart is composed of an outer serous pericardium known as the *epicardium*, an inner endothelial lining known as the *endocardium* and an intermediate muscular stratum lying in between the epicardium and the endocardium known as the *myocardium*. In addition, it contains a limited amount of fibrous tissues which are mostly found opposite the bases of the ventricles and they form a fibrous skeleton into which the muscle fibres are attached.

The **atrium** is composed of three types of muscle fibres, *superficial transverse fibres, deep looped fibres* and *annular fibres.* The superficial transverse fibres form a common investment for both the atria. The deep looped fibres are vertically disposed and are arranged in the form of loops. The extremities of the loops are attached to the fibrous ring surrounding the right atrioventricular ring. Lying deep to this is the annular set of fibres which individually cover each atrium. The annular fibres surround the openings of the great veins and the auricles mainly.

The **ventricles** consist of *superficial, spirally arranged looped fibres* and *deep, figure of eight fibres.* The superficial fibres arise from the fibrous skeleton at the base of the ventricles and pass towards the apex where they meet with the fellow of their opposite side to form a whorl. The deep fibres arise from the region of the base of the papillary muscle, pass to the homolateral ventricular wall, then to the septum and lastly to the base of the papillary muscle of the opposite ventricle.

The atrioventricular orifices, the pulmonary and aortic orifices, are surrounded each by a fibrous ring. The fibrous ring surrounding the aortic orifice is connected with both the atrioventricular orifices by a fibrous band known as the *trigonum fibrosum dextrum* and also it is connected with a similar band of fibres to the pulmonary ring known as the *tendon of the infundibulum.*

The conducting apparatus of the heart. The heart muscle possesses inherent properties of automacity, rythmicity and contractility but these properties of the heart muscle are more pronounced at certain points, at which first, impulse originates and then is propagated in its wall through certain conducting paths and they are as follows:

The primary impulse first arises in the *sino-atrial node* which is a specialised collection of cardiac muscle situated at the upper end of the crista terminalis in the right atrium of the heart. It consists of cross-striated muscle fibres, more slender than the rest of its fibres, and are arranged in a plexiform network. These fibres branch out and are distributed to the walls of the atria. From the sino-atrial node the impulse passes to the *atrioventricular node* which lies in the lower part of the atrial septum immediately above the orifice for the coronary sinus. From the atrioventricular node these specialised fibres form a bundle known as the *atrioventricular bundle* or *bundle of His*. The atrioventricular bundle crosses the right atrioventricular ring and passes to the ventricular septum. Then the bundle ascends upwards in the septum to reach the lower end of the membranous part of the ventricular septum where it divides into right and left branches. The *right branch* passes down the right side of the septum into the septomarginal trabecula and finally reaches the base of the papillary muscles, and beneath the endocardium where they form a plexus of specialised fibres known as the *plexus of Purkinje fibres*.

The *left branch* pierces the membranous septum at the upper border of the muscular septum and reaches the subendocardial space immediately below the junction of the anterior and the right posterior aortic cusps. Then it divides and sub-divides into smaller bundles which are finally distributed to the walls of the left ventricle and its papillary muscles and end in the same manner as in the right ventricle.

N.B. The intimate relation of the left branch of the bundle of His with the aortic cusps explains the reason why it is so often involved in aortic incompetence.

Fibres of Purkinje. They form specialised fibres of the heart and are supposed to be terminal filaments of the bundle of His. They are placed beneath the endocardium and intervenes between it and the myocardium. They form elongated cells which are united at their ends so as to form chains of fibres. Within the centre of each cell there is a granular protoplasm and embedded in it are the two small nuclei of the cell; the peripheral part of each cell presents transverse striations. These fibres are the remains of the embryonic cardiac muscular fibres.

Blood supply of the heart. The right and the left coronary arteries from the ascending aorta supply the heart.

Most of the veins draining the heart open into the coronary sinus except a few known as the venae cordis minimae which open directly into the right atrium. The coronary sinus opens into the right atrium in between the openings of the inferior vena cava and the right atrioventricular orifice.

Nerve supply. The heart is supplied by the vagus and the sympathetic nerves through the cardiac plexus. The vagus nerve is cardio-inhibitory in function and exerts a continuous restraining action on the rate of the heart beat. The sympathetic nerves are cardio-accelatory in function and cause acceleration of the rate of the heart beat.

N.B. It is now evident that sensory pain fibres from the heart pass along the sympathetic fibres to the cervical and upper thoracic sympathetic ganglia. These fibres mainly travel on the left side and partly in the right side. For the above facts now-a-days resection or injection of sclerosing fluids into the stellate ganglion and the upper thoracic sympathetic ganglia are done for the removal of cardiac pains (Angina pectoris).

Peculiarities of the foetal heart. The peculiar features of the foetal heart are the presence of the foramen ovale, prominence of the valve of the inferior vena cava and presence of the ductus arteriosus.

Foramen ovale. The foramen ovale of the foetal heart is an oval opening on the interatrial septum and establishes communication between the right and the left

atria. After fourth month of intrauterine life an annular margin develops at the upper part of the foramen and this margin gradually develops to form the valve of the foramen ovale. This valve prevents regurgitation from the left to the right atrium.

Valve of the inferior vena cava. **The valve of the inferior vena cava, which is rudimentary in postnatal life, is well marked in the foetus. It is a cresentic fold of endocardium that guards the opening of the inferior vena cava and directs the blood from the inferior vena cava to the foramen ovale. The anterior end of the cresentic valve is continuous with the anterior horn of the annulus ovalis.**

Ductus arteriosus. This is a short arterial trunk which connects the commencement of the left pulmonary artery to the arch of the aorta opposite the origin of the left subclavian artery. It conducts most of the blood from the right ventricle to the descending thoracic aorta.

Foetal circulation. The right atrium of the heart receives blood both from the superior and the inferior venae cavae. Although there is some mixing of the

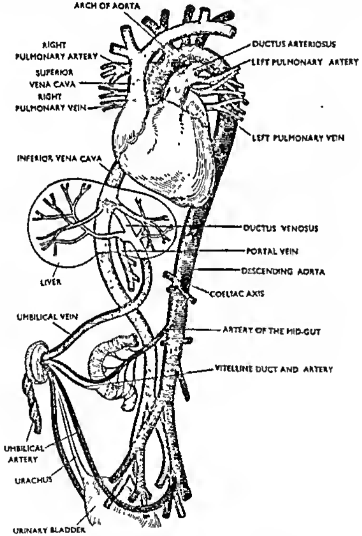


Fig. 601. The foetal circulation. (Diagrammatic).

blood from the two venae cavae in the right atrium, bulk of the blood from the inferior vena cava being guided by the valve of the inferior vena cava passes into the

left atrium through the foramen ovale and the bulk of the blood from the superior vena cava passes to the right ventricle through the right atrioventricular orifice. The left atrium receives bulk of its content from the right atrium and a small quantity from the lungs through the pulmonary veins and then pours out its content into the left ventricle through the left atrioventricular orifice. When the ventricles contract the blood from right ventricle mainly passes into the descending thoracic aorta through the ductus arteriosus and a small quantity passes to the lungs. The blood from the left ventricle mainly passes into the ascending aorta and then through the branches of the arch of the aorta into the upper extremity and the head and the neck. The blood from the descending thoracic aorta passes into the inferior extremity, and a bulk, through the umbilical arteries into the placenta. Purified blood from the placenta returns back into the foetus through the two umbilical veins which unite and carry the same along the free margin of the falciform ligament to the undersurface of the liver. In the porta hepatis it gives out branches to the left and quadrate lobes of the liver and opens into the left branch of the portal vein. A short stout vein, the *ductus venosus* connects the left branch of the portal vein with the inferior vena cava. The amount of blood that enters into the liver returns back into the inferior vena cava by the hepatic veins.

Thus it is evident that inferior vena cava receives purified blood from the umbilical veins and mixed blood from the hepatic veins. The superior vena cava carries impure blood from the head, neck and the superior extremity. The bulk of the blood from the inferior vena cava, which is more pure, passes to the left atrium through the foramen ovale and then into the left ventricle and finally it passes into the head, neck and the superior extremity through the branches of the arch of the aorta. Thus it is found that the head, the neck and the superior extremity receive more pure blood than the rest of the body.

THE ARTERIAL SYSTEM

Ascending aorta. It is the main arterial trunk of the systemic artery and arises from the base of the left ventricle of the heart. It measures about two inches in length and begins at the level of the lower border of the right third costal cartilage. It ascends upwards, forwards and to the right up to the level of the upper border of the right second costal cartilage where it ends by being continuous with the arch of the aorta. In its course upwards it lies behind the right half of the sternum and forms a dilatation opposite its junction with the arch of the aorta and is known as the *bulb of the aorta*. At its origin, opposite the semilunar cusps, it forms localised dilatations known as the *aortic sinuses*.

Relations. The ascending aorta is lodged within the fibrous pericardium and is enveloped by a sheath common to it and the pulmonary trunk derived from the serous pericardium. *Anteriorly* from below upwards, it is in relation to the infundibulum of the right ventricle, origin of the pulmonary trunk, right auricle and the back of the sternum. It is separated from the sternum by the pericardium, pleura, anterior margin of the right lung and the remains of thymus gland. *Posteriorly*, from below upwards, it is related to the left atrium, right pulmonary artery and the right bronchus. *On its right side* are the superior vena cava and the right atrium of the heart. *On the left side* it is related to the pulmonary trunk and the left atrium of the heart.

Branches. Right and left coronary arteries.

Development. The ascending aorta develops from the posterior part of the trunkus arteriosus. Four endothelial cushions, right, left, ventral and dorsal, appear within the trunkus arteriosus. The right and the left cushions meet together and split up the trunkus arteriosus longitudinally into the ascending aorta behind and the pulmonary trunk in front.

Anomalies. The ascending aorta and the pulmonary trunk may arise by a common stem which is a common feature with the fishes and some amphibians. The common trunk may be seen to arise from either the left or the right ventricle or from both. The pulmonary trunk may be seen to arise from the left ventricle and the ascending aorta from the right ventricle. This is due to abnormal position of the endothelial cushions within the trunkus arteriosus.

Coronary arteries. The coronary arteries supply the musculature of the heart, the visceral pericardium and the roots of the ascending aorta and the pulmonary trunk. The two coronary arteries encircle the heart as a crown encircles the head and hence, they are called 'coronaries'. The coronary arteries differ from other arteries in that, as all arteries are fed during systole of the heart, they are fed during diastole of the heart. The muscular contraction of the ventricles of the heart is responsible for the extra gush of blood in all other arteries in each systole of the heart whereas in the coronaries the elastic recoil of the ascending aorta together with the closure of the aortic semilunar valves is responsible for the extra gush of blood during each diastole of the heart. The coronary arteries are examples of functional end-arteries, although, there is free communication between them and they are supposed to be equivalent to enlarged 'vasa vasorum'. The coronary arteries are extremely tortuous in their course.

Coronary arteries are supplied by both vagus and the sympathetic nerves. Stimulation of the vagus causes constriction of the walls of coronary arteries whereas stimulation of the sympathetic causes relaxation of the walls of the coronary arteries.

Right coronary artery. The right coronary artery arises from the anterior aortic sinus and runs at first forwards and to the right between the pulmonary trunk and the right auricle. Then it descends downwards and to the right to reach the right part of the atrioventricular groove from where it passes along the right margin of the heart and reaching the lower end of it, it turns backwards and to the left on the inferior surface with the small cardiac vein and reaches the posterior end of the inferior interventricular groove where it gives its interventricular branch and then ends by anastomosing with the left coronary artery. In its course it supplies the right atrium and the right ventricle by its marginal branch; by its interventricular branch it supplies both the ventricles, which passes along the inferior interventricular groove to the apex of the heart where it anastomoses with interventricular branch of the left coronary artery.

Branches. The *interventricular branch* runs forwards in the inferior interventricular groove to the apex of the heart where it anastomoses with the interventricular branch of the left coronary artery. It supplies both the ventricles and the interventricular septum.

The *ventricular branches* consist of a few small arteries which descend on the anterior surface of the right ventricle, and a marginal branch.

The *marginal branch* is a large one which runs in the inferior margin of the heart and supplies branches to both the surfaces of the right ventricle.

The *atrial branch* runs upwards on the anterior surface of the right atrium and supplies the same.

A few twigs arise from the right coronary to supply the trunk of the ascending aorta and the pulmonary trunk.

Left coronary artery. The left coronary artery arises from the left posterior aortic sinus and runs at first forwards between the pulmonary trunk and the left auricle, then it turns to the left to reach the left end of the atrioventricular groove. Here it curves round the left margin of the heart and passes backwards in company with the coronary sinus to reach the inferior interventricular groove where it anastomoses with the right coronary artery. It supplies branches to the left atrium and the left ventricle. It also provides an interventricular branch which descends downwards in the anterior interventricular groove to the apex of the heart where it ends by anastomosing with the interventricular branch of the right coronary artery.

Branches. The *interventricular branch* of the left coronary artery runs downwards in the anterior interventricular groove to the lower border and the apex of the heart in company with the great cardiac vein, cardiac nerves and lymph vessels. It ends by anastomosing with the interventricular branch of the right coronary artery. It supplies both the ventricles and the interventricular septum.

The *ventricular branches* arise from the main trunk and are distributed to the left surface of the heart and to the posterior part of the inferior surface of the left ventricle.

The *atrial branches* are distributed to the walls of the left atrium.

Some twigs are also distributed to the roots of the ascending aorta and the pulmonary trunk.

Arch of the aorta. *Course.* The arch of the aorta is the direct continuation of the ascending aorta and begins behind the upper part of the manubrium sterni opposite the level of the right sterno-costal articulation. It ends in the descending thoracic aorta opposite the lower border of the left side of the fourth thoracic vertebra. In its course it at first passes upwards, backwards and to the left in front of the trachea and then descends backwards and downwards on the left side of the trachea and finally ends in the descending thoracic aorta opposite the level of the fourth thoracic vertebra. In its course it maintains two arches—one with its convexity upwards and the other with its convexity forwards and to the left.

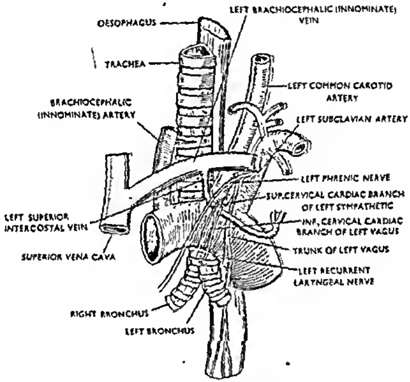


Fig. 602. The arch of the aorta and some of its relations.

Relations. Anteriorly, it is covered by the lungs and pleura which separate it from the back of the manubrium sterni. Crossing superficial to the arch of the aorta are four nerves which descend from above downwards and counted from before backwards they are (1) the left phrenic, (2) the inferior cervical cardiac branch of the left vagus, (3) the superior cervical cardiac branch of the left sympathetic and (4) the trunk of the left vagus nerve. As the vagus nerve crosses the front of the arch of the aorta it gives off its recurrent laryngeal branch which ascends upwards behind the arch and lies at first on the left side of the ligamentum arteriosum and then on its right side. The left superior intercostal vein crosses the left side of the arch obliquely from the left to the right side and lies in between the phrenic nerve in front and the vagus nerve behind.

Posteriorly, the left side of the arch, is in relation with the deep part of the cardiac plexus, the oesophagus and the left recurrent laryngeal nerve, and its right side, is related to the trachea.

Superiorly, the arch of the aorta gives origin to the left subclavian, left common carotid and the brachiocephalic (innominate) arteries in order from the left to the right side and crossing superficial to the origin of these vessels is the left brachiocephalic (innominate) vein.

Inferiorly, the arch is related to the bifurcation of the pulmonary trunk, ligamentum arteriosum, the left bronchus and the left recurrent laryngeal nerve.

Branches. (1) Brachiocephalic (innominate), (2) left common carotid, (3) left subclavian.

Development. The arch of the aorta is formed by contribution from the caudal part of the left portion of the aortic sac, left fourth aortic arch and from the left dorsal aorta upto its fusion with the right dorsal aorta.

Anomalies. *Anomaly of origin.* The arch of the aorta may occasionally be seen to be formed on the right side which is a normal condition in the birds. Occasionally there may be two arches (normal in reptiles) which unite dorsally to form the descending aorta; the trachea and the oesophagus are usually entangled between the two arches.

Anomaly of the branches. The anomalies of branches from the arch of the aorta are due to variations in the extent of fusion-process and absorption of some of the aortic arches into the aortic sac. Thus the branches from the arch of the aorta may either increase in number or they decrease.

Occasionally the arch of the aorta may be found to give origin to the six main arteries of the head and neck and the upper limbs namely, *right subclavian, right common carotid, right vertebral, left common carotid, left vertebral* and the *left subclavian artery*. The brachiocephalic (innominate) and the right common carotid arteries may be found to be absorbed into the arch and five branches namely, *right subclavian, right external carotid, right internal carotid, left common carotid* and the *left subclavian*, may be associated with the arch. Occasionally only the whole of the first part of the left subclavian artery is found to be absorbed into the arch resulting in four branches from the arch namely, the *brachiocephalic* (innominate), the *left common carotid, left vertebral* and the *left subclavian*. Occasionally in addition to the usual three branches the *arteria thyroid ima*, the *internal mammary, inferior thyroid* and the *bronchial artery* may be found to arise from the arch.

The number of branches may also decrease, thus, the right subclavian and a common stem giving origin to right and left common carotids and the left subclavian may be found to arise from the arch. When such condition exists the right *common carotid artery may be found to cross in front of the trachea.* Occasionally there is absence of the brachiocephalic (innominate) artery; the two common carotid arteries, by a common trunk, and the left subclavian artery, arise from the arch; the right subclavian artery in such condition is found to arise from the descending thoracic aorta and runs upwards and to the right behind the oesophagus. Occasionally there are two brachiocephalic (innominate) arteries, one splitting into right subclavian and the right common carotid and the other into left common carotid and left subclavian.

Brachiocephalic (Innominate) artery. The brachiocephalic (innominate) artery is the largest branch of the arch of the aorta and is the extreme right branch from the summit of the arch. It begins from opposite the middle of the back of the manubrium sterni and passes upwards, backwards and to the right to reach the upper border of the back of the right sternoclavicular articulation where it divides into right subclavian and right common carotid arteries.

Relations. Anteriorly, it is related to the back of the manubrium sterni from which it is separated by the origin of the sternohyoid and sternothyroid muscles, remains of the thymus, the left brachiocephalic (innominate) vein, which crosses in front of the roots of the three great vessels, and the right inferior thyroid vein. *Posteriorly*, it is related, below, to the left common carotid artery, and above, to the trachea and the inferior thyroid vein. *On the right side* it is related to the right brachiocephalic (innominate) vein in its upper part and to the superior vena cava in its lower part.

In addition to its terminal branches it occasionally provides a few thymic branches, the arteria thyroid ima and the bronchial artery.

Development. With the change in position of the heart the cranial portion of the aortic sac is drawn apart into right and left horns. The drawn out right horn develops into the brachiocephalic (innominate) artery while the left horn develops into the left common carotid artery.

Anomalies. There may be complete absence of the brachiocephalic (innominate) artery in which the right subclavian and the right common carotid arteries arise directly from the arch of the aorta. Occasionally there may be two brachiocephalic (innominate) arteries, right and left, each arising separately from the arch and bifurcating into the corresponding subclavian and common carotid arteries. Occasionally the two brachiocephalic (innominate) arteries may arise by a common from the arch of the aorta.

COMMON CAROTID ARTERIES

The common carotid arteries are two in number, right and left. The right common carotid artery arises from the brachiocephalic (innominate) artery while the left common carotid artery arises from the arch of the aorta. The relations of the two arteries are almost the same on both the sides except that the left common carotid artery which arises from the arch of the aorta has additional relations within the thoracic cavity.

Left common corotid artery. The left common carotid artery is intermediate in position amongst the three branches of the arch of the aorta. It ascends upwards behind the manubrium sterni to the level of the left sternoclavicular articulation from where it is continued to the neck. Thus the left subclavian artery can be divided into thoracic and cervical parts.

Thoracic part. Course and relations. Anteriorly, it is related to the back of the manubrium sterni being separated by the sternohyoid and the sternothyroid muscles, remains of the thymus and the anterior magrin of the left lung and pleura. Close to its origin it is crossed in front by the left brachiocephalic (innominate) vein. *Posteriorly,* it is related to the trachea (in its lower part only), left edge of the oesophagus, thoracic duct and the left recurrent laryngeal nerve. *On the right side* it is related to the brachiocephalic (innominate) artery in its lower part and to the trachea in its upper part. *On the left side* it is related to the left phrenic, the left vagus, the left subclavian artery and the left lung and the pleura.

It does not provide any branch in the thorax.

Cervical part. Course. The common carotid artery enters the neck behind the sternoclavicular articulation and ascends upwards and backwards under cover of the anterior margin of the sternomastoid upto the level of the upper border of the thyroid cartilage opposite the fourth cervical vertebra where it ends by dividing into external and internal carotid arteries. In the neck together with the internal jugular vein and the vagus nerve it is enveloped by a fascial sheath derived from the deep cervical fascia known as the *carotid sheath.*

Relations. Posteriorly, it is related to the anterior tubercles of the transverse processes of the lower four cervical vertebrae and the origins of the scalenus anterior and the longus cervicis and capitis muscles, and is separated from them by the prevertebral layer of the deep cervical fascia and the sympathetic trunk. At the root of the neck it is related posteriorly to the first portion of the vertebral artery and the origin of the inferior thyroid artery. *On the left* the thoracic duct forms an additional posterior relation to it.

Anteriorly, it is covered by the skin, superficial fascia, platysma and the deep fascia and is overlapped by the anterior margin of the sternomastoid muscle. In the lower part of the neck the inferior belly of the omohyoid, sternohyoid and the sternothyroid muscles intervene between it and the sternomastoid. Higher in the neck, the (common) facial vein crosses in front of it before its termination in the internal jugular vein. The ramus descendens hypoglossi and the ansa hypoglossi usually lie in front of it being separated by the carotid sheath. *Laterally,* it is covered by the sternomastoid being separated by the carotid sheath. *Medially,* it is related to the pharynx, larynx, trachea, oesophagus and the thyroid gland.

Within the carotid sheath it is overlapped by the internal jugular vein laterally and in between the two posteriorly is the vagus nerve.

Except its terminal branches (external and internal carotid arteries) usually it does not provide any branches in the neck. At its point of bifurcation it usually presents a dilatation known as the *carotid sinus.* This is due to thinness of the tunica media with proportionate thickness of the tunica adventitia. The carotid sinus is richly supplied with both sympathetic and parasympathetic (glossopharyngeal) nerves and is concerned in regulating blood pressure in the cerebral arteries. (*Vide* nerve supply of the blood vessels).

Development. The third aortic arch together with the persisting dorsal aorta cranial to it forms the common and the internal carotid arteries.

Anomalies. When the innominate stem is absorbed into the aortic arch the right common carotid artery arises from the arch of the aorta and forms the second branch from the right side, the first branch being the right subclavian. When the right fourth aortic arch is obliterated the right subclavian arises from the descending aorta and the right common carotid in this case forms the first branch of the arch of the aorta from the right side. At its origin from the arch of the aorta the right common carotid artery may be situated either on the right side or on the left side of the median plane; in case of the latter the artery passes either in front of the trachea or behind the oesophagus. Both the common carotids and the right subclavian may also arise by a common stem from the arch of the aorta.

The common carotids may fail to divide or it may divide either at a higher or at a lower level. When it does not divide the branches which usually arise from the external carotid, also arise from it.

Carotid body. It is a small oval body situated behind the common carotid artery immediately before its bifurcation. It is a little less than half an inch in length and is composed of a few lobules connected together by areolar tissue. *Developmentally* it is derived from the mesoderm of the third branchial arch and consequently is intimately related to the artery of the same arch (internal carotid artery). *Structurally* each lobule is composed of polyhedral cells containing sinusoid-like blood vessels and sympathetic nerves. It is richly supplied with nerves derived from the sympathetics and the glossopharyngeal nerves.

External carotid artery:

Course. It begins at the bifurcation of the common carotid artery opposite the upper border of the thyroid cartilage, and ascending upwards it at first lies deep to and then within the substance of the parotid gland and ends by dividing into maxillary (internal maxillary) and superficial temporal arteries opposite the level of the neck of the mandible.

Relations. Opposite the angle of the mandible it is covered superficially by the posterior belly of the digastric and the stylohyoid muscles. Between its origin and the posterior belly of the digastric it is comparatively superficial being overlapped only by the anterior margin of the sternocleidomastoid. It is crossed *superficially* by the (common) facial vein and the hypoglossal nerve in this situation. Above the angle of the mandible it at first lies posterior to the parotid gland and then embedded into its substance. *Medially* it is related to the middle and inferior constrictor muscles of the pharynx and the external and the internal laryngeal nerves. *Postero-laterally* it is related to the internal carotid artery.

N.B. Although it is called the external carotid artery it lies internally of the two carotid arteries.

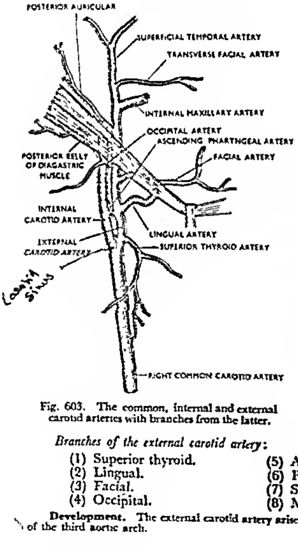


Fig. 603. The common, internal and external carotid arteries with branches from the latter.

Branches of the external carotid artery:

(1) Superior thyroid.
(2) Lingual.
(3) Facial.
(4) Occipital.
(5) Ascending pharyngeal.
(6) Posterior auricular.
(7) Superficial temporal.
(8) Maxillary.

Development. The external carotid artery arises as a branch budding off from the ventral root of the third aortic arch.

supply the mucous membrane of the tongue, palatine tonsil, soft palate and the epiglottis.

Sublingual branch. It arises from the lingual artery at the anterior margin of the hyoglossus muscle and then runs forwards between the genioglossus and mylohyoid muscles to reach the sublingual salivary gland. It supplies the adjacent muscles, the sublingual gland and the mucous membrane of the mouth and gums. One of its branches pierces the mylohyoid muscle and ends by anastomosing with the submental branch of the facial artery. Another branch passes beneath the mandibular gums and ends by anastomosing with the fellow of its opposite side.

Arteria profunda linguae. It is the terminal portion of the lingual artery and has been described with the main artery.

Facial artery. The facial artery (external maxillary) arises from the anterior aspect of the external carotid artery in the neck and after a considerable course in the neck and in the face it ends at the medial palpebral commissure by anastomosing with the dorsal nasal branch of the ophthalmic artery. Thus the artery may conveniently be divided into a cervical part and a facial part.

Cervical part of the facial artery. Course. In the neck, the facial artery arises from the anterior aspect of the external carotid artery in the carotid triangle a little higher than the lingual artery and immediately above the greater cornu of the hyoid bone. From its origin it ascends vertically upwards to the angle of the mandible and then turns downwards forming a loop and descends in the groove on the posterior part of the submandibular gland and then it passes forwards between the lateral surface of the submandibular gland and the medial pterygoid muscle and reaches the lower border of the mandible and finally it arches over the mandible to enter the face at the anterior border of the masseter muscle.

Relations. In its course through the neck it is at first superficial being covered only by the skin, superficial fascia, platysma and the deep fascia, and opposite the angle of the mandible it becomes deep by passing beneath the posterior belly of the diagastric and the stylohyoid muscles. Then it lies in the groove on the posterior aspect of the submandibular gland and subsequently it lies between the gland and the medial pterygoid muscle. Again it becomes superficial where it arches over the mandible to enter into the face. Here the (anterior) facial vein lies posterior to it. At first it lies on the middle constrictor muscle of the pharynx, and higher up, opposite the angle of the mandible it lies on the superior constrictor or it may ascend further up to lie on the styloglossus muscle and in this situation it is separated from the palatine tonsil by the superior constrictor and the styloglossus muscles. Occasionally it may be crossed by the hypoglossal nerve.

Facial part of the facial artery. Course. The facial artery enters the face at the anterior border of the masseter muscle and ascends upwards and forwards across the cheek to reach the angle of the mouth and then ascends further up along the side of the nose to reach the medial palpebral commissure where it ends by anastomosing with the dorsal nasal branch of the ophthalmic artery.

Relations. Opposite the anterior border of the masseter it is superficial and lies under cover of the skin, superficial fascia and the platysma. In its course through the face it is covered by the skin, fat of the cheek, and opposite the angle of the mouth, it lies under the risorius and the zygomaticus major; opposite the medial palpebral commissure it is hidden by the fibres of the levator labii superioris alaeque nasi. It lies successively upon the body of the mandible, buccinator, levator anguli oris and the levator labii superioris alaeque nasi. The (anterior) facial vein lies posterior to it opposite the medial palpebral commissure and then is separated from it by a considerable distance and opposite the anterior border of the masseter, it again comes into intimate relation with the artery and lies immediately posterior to it.

Branches: Cervical part:

(1) Ascending palatine. (3) Glandular.
(2) Tonsillar. (4) Submental.

Facial part:

(1) Superior labial.
(2) Inferior labial.
(3) Lateral nasal.

Ascending palatine. It arises from the facial artery close to its origin and ascends upwards between the styloglossus and stylopharyngeus muscles to the side wall of the pharynx and then ascends to the base of the skull between the superior constrictor muscle of the pharynx and the medial pterygoid muscle. It then reaches the levator palati muscle where it divides into two branches. One branch, accompanying the levator palati muscle, passes between the upper border of the superior constrictor pharyngis and the base of the skull and finally reaches the soft palate. It supplies the adjacent muscles, soft palate and the palatal glands, and anastomoses with the fellow of its opposite side and with the greater palatine artery. The other branch pierces the superior constrictor, supplies the pharyngotympanic tube and the palatine tonsil and ends by anastomosing with the tonsillar and ascending pharyngeal arteries.

Tonsillar branch. It forms the main artery supply to the tonsil and arises from the facial artery in the upper part of the digastric triangle. It ascends upwards between the medial pterygoid and the styloglossus and opposite the upper border of the latter muscle it pierces the superior constrictor and enters into the palatine tonsil.

Glandular branches. They form three or four large branches which supply the submandibular salivary and lymph glands and the adjacent muscles; some of their terminal twigs end in the neighbouring skin.

Submental artery. It is the largest of the branches in the neck and arises from the facial artery as soon as it quits the submandibular gland. It runs forwards on the mylohyoid muscle below the body of the mandible and deep to the anterior belly of the digastric muscle and reaches the chin where it divides into superficial and deep branches. The superficial branch ascends on the chin between the skin and the depressor labii inferioris and ends by anastomosing with the inferior libial artery. The deep branch ascends between the bone and the depressor labii inferioris and ends by anastomosing with the inferior labial and the mental arteries. In its course in the submandibular fossa it supplies the adjacent muscles and anastomoses with the sublingual branch of the lingual artery and with the mylohyoid branch of the inferior dental arteries.

Inferior labial artery. It arises from the facial artery close to the angle of the mouth and soon passes to the lower lip beneath the levator anguli oris. It then pierces the orbicularis oris and runs tortuously between it and the mucous membrane. It supplies the muscles, mucous membranes and glands of the lower lip and anastomoses with the artery of the opposite side and with the mental branch of the inferior dental artery.

Superior labial. It passes to the upper lip and is more tortuous than the preceding artery. It supplies the upper lip and anastomoses with the fellow of its opposite side. It provides alar and septal branches. The alar branch supplies the ala of the nose while the septal branch supplies the vestibule of the septum of the nose.

Lateral nasal. It arises from the facial artery as it runs by the side of the nose. It supplies the sides of the nose and anastomoses with the alar and septal branches of the superior labial artery, dorsal nasal branch of the ophthalmic artery and with the infraorbital branch of the maxillary artery.

Occipital artery. *Course.* The occipital artery arises from the external carotid artery opposite the origin of the facial artery. It ascends upwards and backwards to reach the posterior part of the scalp where it ends by supplying it.

Relations. At first it lies in the carotid triangle where it is superficial being covered only by the skin, superficial fascia, platysma and the deep fascia. Then as it runs upwards and backwards it crosses the internal carotid artery, interna

jugular vein, the hypoglossal (which hooks round it), vagus and the accessory nerves and then passes under cover of the posterior belly of the digastric to reach the interval between the transverse process of the atlas and the mastoid process of the temporal bone. Then it traverses the groove on the mastoid part of the temporal bone where it is covered by the sternomastoid, splenius capitis, longissimus capitis and the posterior belly of the digastric. Finally it becomes superficial again by piercing the aponeurotic connection between the sternomastoid and the trapezius and then divides into branches which pass in the subcutaneous tissue of the scalp and ends by supplying it. In its course upwards and backwards from above the level of the transverse process of the atlas to the scalp it lies successively upon the rectus capitis lateralis, obliquus capitis superior and the semispinalis capitis. Its terminal branches are accompanied by the branches from the greater occipital nerve.

Branches:

(1) Sternomastoid.
(2) Mastoid.
(3) Auricular.
(4) Muscular
(5) Descending.
(6) Meningeal.
(7) Occipital (terminal branches).

Sternomastoid branches. The sternomastoid branches of the occipital artery are two in number, upper and lower. The *upper sternomastoid branch* arises from the occipital artery as it crosses the accessory nerve and then accompanying the nerve it passes superficial to the internal jugular vein and enters into the sternomastoid muscle. The *lower sternomastoid branch* arises from the occipital artery close to its origin and passes downwards and backwards by crossing superficial to the hypoglossal nerve and the internal jugular vein and finally enters into the sternomastoid muscle and anastomoses with the sternomastoid branch of the superior thyroid artery.

Mastoid. It is a small inconstant branch from the occipital artery which enters into the cranial cavity through the mastoid foramen. It ends by anastomosing with the middle meningeal artery and in its course it supplies the mastoid air cells and the dura mater.

Auricular branch. It supplies the back of the concha and ends by anastomosing with the posterior auricular artery.

Muscular branches. The muscular branches supply the digastric, stylohyoid, splenius capitis and the longissimus capitis.

Descending branch. It arises from the occipital artery as it lies on the obliquus capitis superior muscle and divides into superficial and deep branches. The *superficial branch* runs deep to the splenius and ends by anastomosing with the superficial branch of the transverse cervical artery. The *deep branch* runs downwards between the semispinalis capitis et cervicis and anastomoses with the vertebral artery and the deep cervical branch of the costocervical trunk.

Meningeal branches. They enter the cranium through the jugular foramen and the posterior condylar canal and supply the dura mater in the posterior cranial fossa.

Occipital branches. They are the terminal branches which supply the scalp and ascend as high as the vertex. The parent trunk is very tortuous and one of its terminal twigs passes through the parietal foramen to supply the dura mater.

Ascending pharyngeal artery. This is the smallest branch from the external carotid artery and arises from it just after its origin. It is deeply seated and runs vertically upwards on the longus capitis muscle to the base of the skull and lies in between the internal carotid artery and the side-wall of the pharynx. It is crossed by the styloglossus and the stylopharyngeus. At the base of the skull it anastomoses with the ascending palatine branch of the facial artery.

Branches:

(1) Pharyngeal.
(2) Inferior tympanic.
(3) Meningeal.

The *pharyngeal branches* of the ascending pharyngeal artery are two or three in number and they supply the muscles of the pharynx. One of the branches passes through the gap between the upper border of the superior constrictor muscle of the pharynx and the base of the skull and accompanying the levator muscle it enters the soft palate. It may replace the ascending palatine branch of the facial artery.

The *inferior tympanic artery* is a small branch which enters the tympanic cavity through the tympanic canaliculus in company with the tympanic branch of the glossopharyngeal nerve. It supplies the medial wall of the tympanic cavity and ends by anastomosing with the other tympanic arteries.

The *meningeal branches* are several small branches which supply the dura mater. They enter the cranial cavity through the anterior condylar canal, jugular foramen and the foramen lacerum.

Posterior auricular artery. It is a small branch from the external carotid artery and arises from it as it is crossed by the posterior belly of the digastric and the stylohyoid muscles. It runs upwards and backwards under cover of the parotid gland to reach the groove between the cartilage of the ear and the mastoid process where it ends by dividing into auricular and occipital branches.

Auricular. It supplies the posterior part of the auricle and ends by anastomosing with the posterior and auricular branches of the superficial temporal artery.

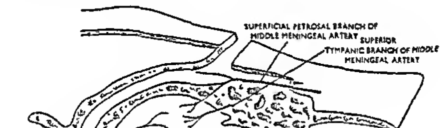


Fig. 605. The arteries supplying the middle-ear.
Note the distribution of the arteries from different sources. With the kind permission from: W. H. Hollinshead, Ph.D.: Anatomy for the Surgeon; Paul B. Hoeber; I.N.C., New York.

Occipital. It passes laterally crossing the mastoid process and reaches the posterior part of the scalp where it ends by anastomosing with the occipital artery.

Stylomastoid branch. The stylomastoid branch of the posterior auricular artery enters the stylomastoid foramen and then enters into the tympanic cavity. It supplies the tympanic cavity, tympanic antrum, mastoid air cells and the semicircular canals and anastomoses with the superficial petrosal branch of the middle meningeal artery.

Superficial temporal. It is the smaller terminal branch of the external carotid artery and arises from the same opposite the neck of the mandible within the substance of the parotid gland. It then crosses the posterior root of the zygomatic process and ascends vertically upwards under cover of the auricularis anterior for about two inches and ends by dividing into anterior and posterior branches. Within the parotid gland it is crossed by the zygomatic and the temporal branches of the facial nerve. Outside the parotid gland the auriculotemporal nerve lies posterior to it and the temporal branch of the facial nerve lies anterior to it. It gives out the following branches;

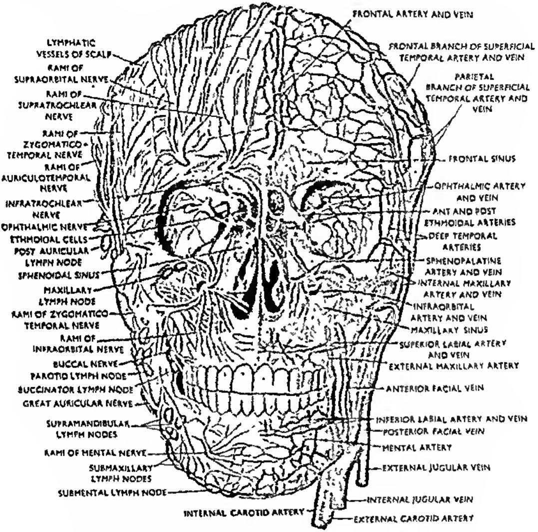


Fig. 606. The arteries and nerves of the face and scalp (seen from the front). With the kind permission from Lederle Laboratories—drawn by Mr. Paul Peck.

Transverse facial. It arises from it from within the parotid gland and crosses superficial to the masseter muscle lying above the parotid duct and supplies the parotid gland with its ducts, the masseter muscle and the adjacent skin. It anastomoses with facial, infraorbital, buccal and massetric arteries.

Auricular branches. They are distributed to the lobule, the anterior part of the auricle and external auditory meatus and anastomoses with the posterior auricular artery.

Zygomatic artery. It runs along the upper border of the zygomatic arch between the two layers of the temporal fascia to the lateral angle of the orbit where it anastomoses with the lacrimal and palpebral branches of the ophthalmic artery.

Middle temporal artery. It arises from the superficial temporal artery above the zygomatic arch and it pierces the temporal fascia, supplies the temporalis muscle and ends by anastomosing with the deep auricular branch of the maxillary artery.

Anterior branch. It runs upwards and forwards to the frontal eminence and ends by anastomosing with the fellow of its opposite side and with the supraorbital and supratrochlear arteries. It is very tortuous in its course.

Posterior branch. It curves backwards to the posterior part of the side of the head superficial to the temporal fascia and ends by anastomosing with the occipital and posterior auricular arteries.

Maxillary artery (internal maxillary). It is the larger terminal branch of the external carotid artery and begins from opposite the neck of the mandible. At its origin it runs horizontally forwards between the neck of the mandible and the sphenomandibular ligament and crossing the *inferior dental nerve* it reaches the lower border of the lateral pterygoid muscle. Then it ascends upwards crossing superficial to the lower head of the lateral pterygoid muscle and then it passes medially between the two heads of the lateral pterygoid muscle and enters the pterygopalatine fossa through the pterygomaxillary fissure and ends by dividing into its terminal branches.

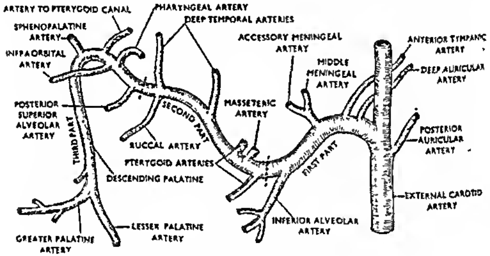


Fig. 607. The maxillary artery and its branches.

The portion of the maxillary artery extending from its origin to the lower border of the lateral pterygoid muscle constitutes its first part, the portion extending over the lateral pterygoid muscle constitutes its *second or pterygoid* part and the portion extending from between the two heads of the lateral pterygoid muscle to the pterygopalatine fossa constitutes its third or the pterygopalatine part.

Branches from the first part of the maxillary artery (5 branches):
(1) Deep auricular.
(2) Anterior tympanic.
(3) Middle meningeal.
(4) Accessory meningeal.
(5) Inferior dental.

Branches from the second part (4 branches):
(1) Deep temporal.
(2) Pterygoid.
(3) Masseteric.
(4) Buccal.

Branches from the third part (6 branches):
(1) Posterior superior dental.
(2) Infraorbital.
(3) Greater palatine.
(4) Pharyngeal.
(5) Artery of the pterygoid canal.
(6) Sphenopalatine.

Deep auricular artery. It is the first branch of the (internal) maxillary artery and ascends upwards behind the mandibular joint where it gives a twig to the same. Then it pierces the cartilage of the pina of the ear and ends by supplying the external surface of the tympanic membrane.

Anterior tympanic artery. It is smaller than the preceding artery and ascends upwards behind the mandibular joint and then it enters the tympanic cavity through the petrotympanic fissure. In the tympanic cavity it ramifies on the internal surface of the tympanic membrane; by anastomosing with the posterior tympanic branch of the stylomastoid artery it forms a vascular ring around the tympanic membrane. It also anastomoses with the caroticotympanic and the artery of the pterygoid canal.

Middle meningeal artery. It is the largest of the meningeal arteries and arises from the first portion of the maxillary artery. At its origin it lies between the spheno-mandibular ligament and the lateral pterygoid muscle. Then as it ascends upwards behind the lateral pterygoid muscle it is encircled by the two roots of the auriculo-temporal nerve and lies on the tensor palati muscle and is crossed by the chorda tympani nerve and then it enters the cranial cavity through the foramen spinosum accompanied by the meningeal branch of the mandibular nerve (nervus spinosus); then it leaves the nerve and runs forwards and laterally in a groove on the squamous part of the temporal bone and then divides into anterior and posterior branches.

The **anterior branch** crosses the greater wing of the sphenoid bone and then enters in a groove on the anteroinferior angle of the parietal bone; here it divides into branches which ascend upwards and backwards between the dura mater and the cranium to the summit of the cranial cavity where it ends by anastomosing with the similar branches from the opposite side. One of its branches is large and ascends vertically upwards at a distance of about half an inch from the coronal suture.

The **posterior branch** runs upwards and backwards in the posterior part of the squamous part of the temporal bone and reaches the parietal bone a little in front of its posteroinferior angle and finally divides into branches which supply the dura mater in the posterior part of the cranium and end by anastomosing with the branches from the opposite side.

Branches:

(1) **Ganglionic.** It supplies the trigeminal ganglion.

(2) **Superficial petrosal.** It enters the tympanic cavity through the hiatus of the greater superficial petrosal nerve and supplies the tympanic cavity.

(3) **Superior tympanic.** It enters the tympanic cavity through the canal for the tensor tympani muscle and supplies the tympanic cavity.

(4) **Temporal branches.** They come out in the temporal fossa by passing through minute foramina in the greater wing of the sphenoid bone and end by anastomosing with deep temporal arteries.

(5) **Orbital.** It enters the orbit through the superior orbital fissure and ends by anastomosing with the recurrent meningeal branch of the lacrimal artery.

(6) **Terminal** (anterior and posterior).

Accessory meningeal artery. It arises either from the (internal) maxillary or from the middle meningeal artery and enters the cranial cavity through the foramen ovale. In the cranial cavity it supplies branches to the dura mater and the trigeminal ganglion.

Inferior alveolar (dental) artery. It arises from the lower border of the first part of the maxillary artery and descends on the medial aspect of the ramus of the mandible to the mandibular foramen. It then enters the mandibular canal in company with

the inferior alveolar (dental) nerve and reaching the level of the first premolar tooth it ends by dividing into incisive and mental branches. In its course to the mandibular foramen it intervenes between the ramus of the mandible and the sphenomandibular ligament and lies posterior to the inferior alveolar (dental) nerve. Just before it enters into the mandibular canal it gives out its mylohyoid branch and near its origin it gives out its lingual branch which accompanies the lingual nerve and supplies the tongue.

Mylohyoid artery. It arises from the inferior dental artery and after piercing the sphenomandibular ligament it descends on the mylohyoid groove together with the mylohyoid nerve. It ramifies on the surface of the mylohyoid muscle and anastomoses with the submental branch of the facial artery.

Incisive branch. It reaches the median plane by passing below the incisor teeth and ends by anastomosing with the fellow of its opposite side. In its course it supplies the incisor teeth.

Mental branch. It comes out through the mental foramen and supplies the chin It anastomoses with the submental and the inferior labial branches of the facial artery.

Deep temporal branches. Deep temporal branches are anterior and posterior and they ascend to the temporal fossa between the temporalis muscle and the pericranium. They supply the temporalis muscle and anastomose with the middle temporal artery. The anterior deep temporal artery gives a branch which pierces the zygomatic bone and the greater wing of the sphenoid and anastomoses with the lacrimal artery.

Pterygoid branches. They supply the pterygoid muscles.

Masseteric artery. It is a small branch from the (internal) maxillary artery and accompanying the masseteric nerve it passes through the mandibular notch behind the tendon of the temporalis muscle and reaches the deep surface of the masseter muscle. It ends by supplying the muscle and anastomoses with the masseteric branch of the facial and with the transverse facial artery within the muscle.

Buccal artery. It runs downwards and forwards between the medial pterygoid and the insertion of the temporalis muscle and accompanies the buccal branch of the mandibular nerve. It reaches the superficial aspect of the buccinator muscle which it supplies and anastomoses with the infraorbital and the branches from the facial artery.

Posterior superior alveolar (dental) artery. It is the first branch of the pterygopalatine portion of the maxillary artery and arises from it as it passes to the pterygopalatine fossa. It enters the maxilla through the posterior dental canals and supplies the mucous membrane of the maxillary antrum and the premolar and the molar teeth.

Infraorbital artery. It arises usually in common with the preceding artery and enters the orbital cavity through the posterior part of the inferior orbital fissure. It accompanies the infraorbital nerve and runs in the infraorbital groove or canal on the floor of the orbit. It emerges to the face through the infraorbital foramen and lies under cover of the levator labii superioris. In the face its terminal branches anastomose with the branches of the facial artery, the transverse facial, the buccal arteries and the dorsal nasal branch of the ophthalmic artery. In the orbit it gives out orbital branches which supply some twigs to the rectus inferior, obliquus inferior and the lacrimal sac and by its anterior superior dental arteries supplies the maxillary air sinus, the incisors and the canine tooth.

Greater palatine artery. It arises from the (internal) maxillary artery within the pterygopalatine fossa and accompanying the greater palatine nerve it descends through the greater palatine canal to the roof of the mouth. Then it runs forwards in a groove between the alveolar and the palatal processes to the incisive fossa and then enters the nasal cavity through the incisive canal and ends by anastomosing with the sphenopalatine artery. It gives out its lesser palatine branches which reach

the roof of the mouth through the lesser palatine foramina and anastomose with the ascending palatine artery. They supply the soft palate and the tonsils.

Pharyngeal artery. It is a small branch which accompanies the pharyngeal nerve from the sphenopalatine ganglion and runs backwards through the palatino-vaginal canal and finally is distributed to the sphenoidal air sinus, pharyngo-tympanic tube and the roof of the nasal cavity.

Artery of the pterygoid canal. It accompanies the pterygoid nerve and runs backwards through the pterygoid canal and ends by supplying the auditory (pharyngo-tympanic) tube and the pharyngeal wall. It provides a branch which enters the tympanic cavity and ends by anastomosing with the other tympanic arteries.

Sphenopalatine artery. It is the terminal portion of the (internal) maxillary artery and enters the nasal cavity through the sphenopalatine foramen. It provides *posterior lateral nasal branches* which supply the frontal, maxillary, sphenoidal and ethmoidal air sinuses, the conchae and the meatuses of the nose and anastomose with ethmoidal arteries and the nasal branches of the greater palatine artery. Its terminal portion breaks up into posterior septal branches. One of these branches descends on the groove on the vomer to the incisive canal and anastomoses with the greater palatine artery and the septal branch of the superior labial artery. The other branches end by anastomosing with the ethmoidal arteries.

INTERNAL CAROTID ARTERY

The internal carotid artery begins at the bifurcation of the common carotid artery opposite the upper border of the thyroid cartilage and ascending upwards through the neck it enters the carotid canal of the petrous part of the temporal bone and emerges from the latter into the cranial cavity where it is at first contained within the cavernous sinus and then emerges out of it to reach the base of the brain where it divides into branches which are distributed to the brain. Thus the internal carotid artery may be divided into *cervical*, *petrous*, *cavernous* and *cerebral parts*.

Cervical part of the internal carotid artery. The internal carotid artery in the neck is contained within the upward prolongation of the carotid sheath along with the internal jugular vein and the vagus nerve. *Posteriorly* it lies mostly on the longus capitis muscle being separated by the prevertebral fascia, superior laryngeal nerve, superior cervical sympathetic ganglion and the carotid sheath. *Anteriorly* below the posterior belly of the digastric it is overlapped by the sterno-mastoid muscle and is crossed by the hypoglossal nerve, (common) facial vein and the occipital artery being separated by the carotid sheath. Above it passes deep to the posterior belly of the digastric, stylohyoid, styloid process and the other styloid group of muscles. The styloid process with the styloid group of muscles separate it from the parotid gland, external carotid artery, retromandibular (posterior facial) vein and the facial nerve. Beneath the stylopharyngeus muscle it is crossed by the glossopharyngeal nerve and the pharyngeal branch of the vagus nerve. *Laterally* it is related to the internal jugular vein and the vagus nerve. Just before it enters into the carotid canal of the petrous part of the temporal bone, the glossopharyngeal, vagus, accessory and the hypoglossal nerves and the internal jugular vein lie anterolateral to it.

The cervical part of the internal carotid artery does not provide any branches.

The petrous part of the internal carotid artery. Traverses through the carotid canal in the petrous part of the temporal bone and then enters into the cavernous part.

Cavernous and cerebral parts of the internal carotid artery. The cavernous part of the internal carotid artery lies within the cavernous sinus and is separated from the blood of the sinus by the lining endothelium of the same. Infero-lateral to it is the abducent nerve and more laterally are the oculomotor, trochlear, ophthalmic and the maxillary nerves. It perforates the dura mater forming the roof of the sinus medial to anterior clinoid process. Then it runs backwards below the optic nerve and runs between the optic and the

oculomotor nerves to the anterior perforated substance and lies on the medial side of the lateral cerebral sulcus where it ends by dividing into anterior and middle cerebral arteries.

Branches:

Cavernous part:
 Cavernous, Hypophyseal, Meningeal, Ophthalmic.
Cerebral part:
 Anterior cerebral, Middle cerebral, Posterior communicating, Anterior choroid.

Development. The persisting dorsal aorta cranial to the third aortic arch develops into the internal carotid artery.

Anomalies. The internal carotid artery may arise directly from the arch of the aorta. It may be completely absent, particularly on the left. The upper extremity of the internal carotid may be absent and the posterior communicating artery from the posterior cerebral becomes prominent to replace the middle cerebral artery. Occasionally the internal carotid artery may provide a large meningeal branch to the posterior cranial fossa. Some of the branches from the external carotid may also arise from the internal carotid.

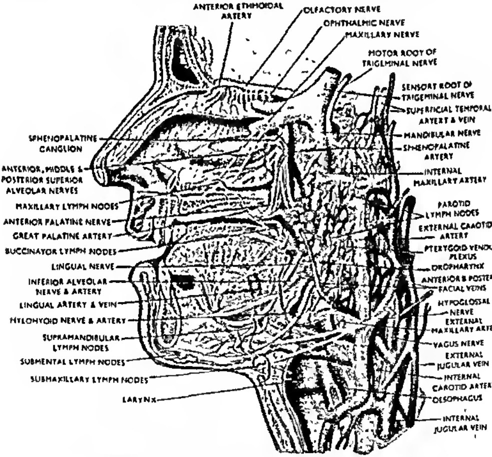


Fig. 608. The vessels and nerves of neck, mouth and nasal cavities.
With the kind permission from Lederle Laboratories—drawn by Mr. Paul Peck.

Cavernous branches. They form numerous small arterial twigs which supply the trigeminal ganglion and the walls of the cavernous and the inferior petrosal sinuses. A few of them anastomose with the branches of the middle meningeal artery.

Hypophyseal branches. They are one or two small branches which supply the hypophysis cerebri or the pituitary body.

Meningeal branch. It is a small branch supplying the dura mater in the anterior cranial fossa; it ends by anastomosing with the meningeal branch of the posterior ethmoidal artery.

The ophthalmic artery. It arises from the internal carotid artery opposite the level of the optic foramen and passes through the same lying inferolateral to the optic nerve and enters into the orbital cavity and then soon crosses the optic nerve from lateral to the medial side to reach the medial wall of the orbit. Then it passes to the medial margin of the front of the orbit where it breaks up into its terminal branches, frontal and dorsal nasal. The following are the branches of ophthalmic artery:

Lacrimal artery. It accompanies the lacrimal nerve and supplies the lacrimal gland and the conjunctiva and the eyelids. Opposite the lateral palpebral commissure it divides into two *lateral palpebral arteries* which anastomose with the medial palpebral arteries to form the *arcus tarseus*. It also gives out zygomatic and recurrent meningeal branches. The *zygomatic branches* are usually two in number,

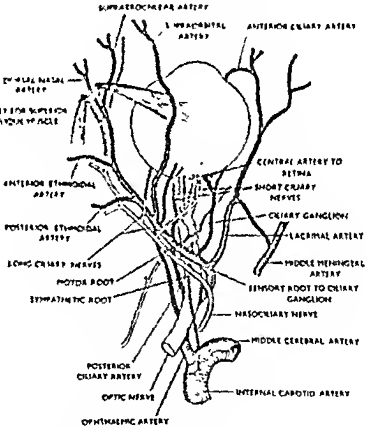


Fig. 609. The ophthalmic artery with its branches.
Note its course and its branches of distribution.

one passes to the temporal fossa by passing through the zygomatico-temporal foramen and ends by anastomosing with the deep temporal arteries; the other branch passes to the face through the zygomatico-facial foramen and ends by anastomosing with the transverse facial branch of the superficial temporal artery. The *recurrent meningeal branch* of the lacrimal artery runs backwards and enters into the cranial cavity through the lateral part of the superior orbital fissure, lying outside the annulus tendineus communis and ends by anastomosing with a branch of the middle meningeal artery.

Muscular branches. They supply the muscles of the eyeball.

Arteria centralis retinae. It arises from the ophthalmic artery just beyond the optic foramen and pierces the optic nerve about half an inch behind the eyeball. It supplies the retina.

Ciliary arteries. They are the anterior ciliary and the short and the long posterior ciliary arteries. The ***short posterior ciliary arteries*** are about six or seven in number and they accompany the short ciliary nerves and after piercing the sclera around the entrance of the optic nerve, end in the choriocapillary layer of the choroid and in the region of the ora serrata; they anastomose with long posterior and anterior ciliary arteries. The ***anterior ciliary arteries*** arise from the lacrimal or muscular branches of the ophthalmic artery in the anterior part of the eyeball and pass under the conjunctiva to form an arterial circle; finally they pierce the sclera immediately behind the sclero-corneal junction. The ***long posterior ciliary arteries*** are two in number, and each lies on each side of the optic nerve, and after piercing the sclera they reach the choroid and end by anastomosing with the short posterior ciliary and anterior ciliary arteries.

Supra-orbital artery. It accompanies the supra-orbital nerve and passes to the scalp.

Ethmoidal arteries. They are anterior and posterior and pass to the nasal cavity through the corresponding ethmoidal foramen.

Dorsal nasal. It is one of the terminal branches and ends by anastomosing with the facial artery.

Supratrochlear artery. It is one of the terminal branches and accompanies the supratrochlear nerve and supplies the scalp.

Anterior cerebral. It is the smaller terminal branch of the internal carotid artery and begins at the medial margin of the lateral cerebral fissure on the medial side of the olfactory nerve. It passes to the commencement of the longitudinal cerebral fissure where it is connected to the fellow of its opposite side by a short communicating trunk known as the *anterior communicating artery.* Then it enters the longitudinal cerebral fissure and curves backwards over the genu and the trunk of the corpus callosum and reaches the posterior end of the splenium where it ends by anastomosing with the posterior cerebral artery. It divides into central and cortical branches. The *central branches* enter the brain through anterior perforated substance and supply the rostrum, lamina terminalis, septum lucidum, lentiform nucleus and the head of the caudate nucleus. The *cortical branches* divide into orbital, frontal and parietal groups of branches which supply the respective surfaces of the brain.

Middle cerebral. This is the larger terminal branch of the internal carotid artery and is its direct continuation. At its commencement it lies lateral to the optic chiasma and soon enters into the stem of the lateral cerebral fissure. In its further course it is contained within the lateral cerebral fissure on the superolateral surface of the cerebral hemisphere and ramifies into the adjoining portions of the brain. The middle cerebral artery divides into central and cortical branches.

The *central branches* form a group of blood vessels which penetrate into the brain through the anterior perforated substance. After entering the substance of the brain they arrange into medial and lateral striate groups of blood vessels. The *medial striate group* penetrates through the lentiform nucleus and supplies the lentiform and the caudate nuclei and the internal capsule. The *lateral striate group* runs upwards over the lateral aspect of the lentiform nucleus and turns medially and penetrates the lentiform nucleus and the internal capsule and finally reaches the caudate nucleus to supply it. One of the arteries of the lateral striate group is larger than the rest. It is called the *artery of the cerebral haemorrhage* (Charcot) or the *lenticulostriate artery.* This artery commonly ruptures in cases of cerebral haemorrhages and is thus called the artery of the cerebral haemorrhage.

The *cortical branches* are grouped into orbital, frontal and parietal branches. The orbital branches supply the lateral part of the orbital surface and the inferior frontal gyrus. The frontal branches supply the precentral gyrus and the middle frontal gyrus. The parietal branches supply the lower part of the superior parietal and the whole of the inferior parietal lobules and the post-central gyrus. The temporal branches are distributed to the lateral aspect of the temporal lobe of the brain.

Posterior communicating. It arises from the back of the internal carotid artery and runs backwards below the optic tract and above the oculomotor nerve and ends by anastomosing with the posterior cerebral artery. In its course it supplies the optic tract, the cerebral peduncles and the floor of the third ventricle.

SUBCLAVIAN ARTERY

The left subclavian artery arises from the arch of the aorta and after a short course in the thorax it enters the neck. The right subclavian artery arises from the brachiocephalic (innominate) artery. In the neck the scalenus anterior muscle crosses in front of the artery and sub-divides it into three parts—first, second and the third. The first part extends from its origin to the medial border of the scalenus anterior, the second part lies under cover of the scalenus anterior while the third part extends from the lateral border of the scalenus anterior to the outer border of the first rib where it is continued as the axillary artery. The first portion of the left subclavian artery is longer than that of the right.

Left subclavian artery. It arises from the left portion of the arch of the aorta and ascends upwards to the root of the neck and then is continued to the neck.

Anteriorly, it is related to the left side of the back of the manubrium sterni being separated by the sternohyoid and sternothyroid muscles, remains of the thymus and the anterior margin of the left lung and the pleura. At its origin it lies posterior to the left common carotid artery and is crossed by the commencement of the left brachiocephalic (innominate) vein. The left phrenic and the left vagus nerves intervene between it and the left common carotid artery. *Posteriorly,* it comes into relation with the left lung and the pleura. *Medially,* it is related to the trachea, left recurrent laryngeal nerve, oesophagus and the thoracic duct. *Laterally,* it is related to the left lung and the pleura and forms its impression on the mediastinal surface of the left lung in front of its apex.

It does not provide any branch in the thorax.

First portion of the subclavian artery in the neck. The first portion of the subclavian artery enters the neck behind the upper part of the sternoclavicular articulation and arches upwards and laterally to reach the medial margin of the scalenus anterior where it becomes continuous with the second part. *Anteriorly,* it is covered by the skin, superficial fascia, platysma, deep fascia, clavicular origin of the sternomastoid and the origins of the sternohyoid and the sternothyroid muscles. It is crossed in front by the internal jugular vein, vagus and cardiac nerves and the vertebral veins. Close to the scalenus anterior it is encircled by the ansa subclavia from the sympathetic nerve and on the left side, in addition, it is crossed by the left phrenic nerve and the thoracic duct. *Postero-inferiorly* it is related to the apex of the lung but is separated from it by the pleura and the suprapleural membrane, the recurrent laryngeal nerve and the ansa subclavia. The recurrent laryngeal nerve comes into relation with the subclavian artery on the right side only and after its origin from the right vagus nerve as it crosses in front of the artery it hooks round below it. *Posteriorly* it is related to the sympathetic trunk, longus cervicis muscle, right recurrent laryngeal nerve and the first thoracic vertebra.

Second portion of the subclavian artery. The second portion of the subclavian artery lies behind the scalenus anterior and forms an arch, the summit of which is about 3/4 inch distant from the clavicle. *Anteriorly* it is covered by the skin, superficial fascia, platysma, deep fascia, sternomastoid and the scalenus anterior muscles.

On the right side the phrenic nerve crosses in front of it being separated by the scalenus anterior. *Postero-inferiorly* it is related to the lung and pleura. *Antero-inferiorly* it is related to the subclavian vein being separated by the scalenus anterior. *Superiorly* it comes into relation with the upper and the middle trunks of the brachial plexus.

Branches: From the first part:

(1) Vertebral.
(2) Thyrocervical.
(3) Internal thoracic (mammary).
(4) Costocervical trunk (left side).

From the second part (right side): Costocervical trunk.

Development. The left subclavian artery is formed by the left seventh intersegmental branch of the left dorsal aorta. The right subclavian artery is formed by the right fourth aortic arch, right dorsal aorta between the right fourth and seventh intersegmental arteries, and a part by the right seventh intersegmental artery.

Anomalies. The right subclavian may arise directly from the arch of the aorta. It may also arise from a common stem from the arch of the aorta which gives origin to right subclavian, right common carotid and the left common carotid arteries. The right subclavian may occasionally arise from the descending aorta and runs upwards and to the right behind the oesophagus. The left subclavian may also arise by a common stem with the left common carotid.

The other anomalies associated with the subclavian artery are its abnormal position and branches. The artery may pass in front of the scalenus anterior muscle or it may pierce through it. The subclavian vein may accompany it. The branches of the subclavian artery vary in their number and in their points of origin.

Vertebral artery. The vertebral artery arises from the postero-superior part of the first portion of the subclavian artery and ascends upwards to reach the foramen transversarium of the sixth cervical vertebra and then passes upwards through the foramina in the transverse processes of the cervical vertebrae and then winds backwards behind the lateral mass of the atlas and reaches the groove on the upper surface of the posterior arch of the atlas. Finally it enters the cranium through the foramen magnum and reaching the lower part of the pons it unites with the fellow of its opposite side to form the basilar artery. It is divisible into four parts. The first part begins from its origin to the foramen transversarium of the sixth cervical vertebra, the second part extends from the latter to the foramen transversarium of the atlas, the third part is contained in the sub-occipital triangle while the fourth part is contained within the cranial cavity.

First part of the vertebral artery. The first part of the vertebral artery begins from the postero-superior part of the first portion of the subclavian artery and extends upto the foramen transversarium of the sixth cervical vertebra where it is continuous with the second part. It ascends upwards and backwards between the medial margin of the scalenus anterior and the longus cervicis muscle. *Anteriorly* it is related to the common carotid artery and the vertebral vein and is crossed by the inferior thyroid artery. *On the left side,* in addition, it is crossed by the thoracic duct. *Posteriorly* it is related to the transverse process of the seventh cervical vertebra, the anterior primary rami of the seventh and the eighth cervical nerves and the inferior cervical sympathetic ganglion.

Second part of the vertebral artery. The second part of the vertebral artery transverses through the foramina transversaria of the upper six cervical vertebrae. It is accompanied by the vertebral plexus of sympathetics derived from the inferior cervical sympathetic ganglion and the vertebral plexus of veins which unite in the lower part of the neck to form the vertebral vein. In its course it lies in front of the anterior primary rami of the cervical nerves.

Third part of the vertebral artery. The third part of the vertebral artery begins as a continuation of its second part from the foramen transversarium of the atlas where it lies on the medial side of the rectus capitis lateralis and ends in the fourth part by entering the vertebral canal below the lower arched border of the posterior occipital membrane. From its origin it arches backwards on the lateral

mass of the atlas and reaches the groove on the upper surface of the posterior arch of the atlas where it is contained in the sub-occipital triangle being covered by the semispinalis capitis. In its course it is accompanied by the anterior primary ramus of the suboccipital nerve (first cervical nerve) which lies medial to it. The posterior primary ramus of the suboccipital nerve lies below it and intervenes between it and the posterior arch of the atlas and at once divides into branches which supply the suboccipital muscles.

Fourth part of the vertebral artery. The fourth part of the vertebral artery enters the cranial cavity through the foramen magnum by piercing the dura mater and the arachnoid immediately above the posterior arch of the atlas. It at first runs upwards in front of the first ligamentum denticulatum and then passes in front of the roots of the hypoglossal nerve. Then it inclines upwards and medially in front of the medulla oblongata to reach the lower border of the pons opposite the median plane where it unites with the fellow of its opposite side to form the basilar artery.

Branches:

Cervical:	*Cranial:*
(1) Muscular branches.	(1) Posterior spinal artery.
(2) Spinal branches.	(2) Anterior spinal artery.
(3) Meningeal branches.	(3) Posterior inferior cerebellar artery.

The **muscular branches** arise from the vertebral atery in the neck and supply the deep muscles of the neck and the suboccipital muscles and end by anastomosing with the descending branch of the occipital, and the deep and the ascending cervical arteries.

The **spinal branches** arise in series from the second part of the vertebral artery and enter into the vertebral canal through the intervertebral foramina. Each artery after entering into the vertebral canal divides into two branches, one runs along with the roots of the spinal nerves to the spinal cord where it ends by anastomosing with the anterior and the posterior spinal arteries. The other branch divides into ascending and descending branches which run upwards and downwards respectively on the posterior surfaces of the bodies of the vertebrae and end by anastomosing with the similar branches from above and below. They supply the intervertebral discs, and the periosteum and the bodies of the vertebrae.

The **meningeal branches** consist of one or two twigs which arise from the third part of the vertebral artery before it pierces the dura mater and they enter into the posterior cranial fossa where they end by anastomosing with the meningeal branches from the occipital and the ascending pharyngeal arteries.

The **posterior spinal artery** usually arises from the posterior inferior cerebellar branch of the vertebral artery, but occasionally, it may arise from the vertebral artery directly. It runs downwards and backwards on the side of the medulla oblongata and then descends downwards as two branches, one in front of the dorsal roots and the other behind them, to the lower end of the medulla spinalis where they end by anastomosing with the anterior spinal artery. In their course downwards the posterior spinal arteries are reinforced by uniting with the spinal branches of the vertebral, ascending cervical, posterior intercostal and the lumbar arteries.

The **anterior spinal artery** arises from the vertebral artery a little below the lower border of the pons and descends downwards and medially to reach the front of the decussation of the pyramids where it unites with the fellow of its opposite side to form a single median artery. The single trunk thus formed descends on the pia-mater in the anterior median fissure under cover the linea splendens and reaching the lower end of the spinal cord it runs along the filum terminale. In its course downwards it is reinforced by spinal branches from the vertebral, ascending cervical, posterior intercostal and lumbar arteries. It supplies the spinal meninges, the grey matter including the base of the posterior horn of both sides and the adjoining

white matter. In the cranial cavity branches from it supply the anterior and median parts of the medulla oblongata and the hypoglossal triangle and the hypoglossal nucleus. In the lower part of the vertebral canal it also provides branches to supply the cauda equina.

The **posterior inferior cerebellar artery** is the largest branch of the vertebral artery and arises from it close to the lower end of the olive of the medulla oblongata. After its origin it takes a tortuous course backwards and downwards around the medulla oblongata and then runs upwards to the lower border of the pons; in its course to the latter it lies behind the roots of the eleventh and the tenth cranial nerves. From the lower end of the pons it turns downwards along the infero-lateral aspect of the fourth ventricle and then it runs laterally into the vallecula of the cerebellum where it ends by dividing into a medial and a lateral branch. The *medial branch* runs backwards between the inferior vermis and the cerebellar hemisphere and supply both of them. The *lateral branch* runs to the lower surface of the cerebellar hemisphere and ends by anastomosing with the anterior inferior cerebellar and the superior cerebellar branches of the basilar artery.

The trunk of the posterior inferior cerebellar artery supplies branches to the choroid plexus of the fourth ventricle and to the medulla oblongata. Some of the branches to the medulla supply the nuclei of the vagus, accessory and the glossopharyngeal nerves and to the spinothalamic tract, the spinal tract of the trigeminal and the vestibular roots of the stato-acoustic nerve. A special branch also supplies the dentate nucleus of the cerebellum.

Development. The *first part* of the vertebral artery develops from the dorsal branch of the seventh cervical intersegmental artery. The *second part* arises from the post-costal longitudinal anastomoses connecting the upper six cervical intersegmental arteries whose stems of origin from the dorsal aorta undergo regression. The spinal branch of the first cervical intersegmental artery enlarges to form the *third part* of the vertebral artery and the pre-neural anastomosis of this spinal branch forms the *fourth part* of the vertebral artery.

Anomalies. The vertebral artery shows variations in respect of its origin, course, termination and in providing branches.

The right vertebral artery may arise from the arch, descending aorta or from the common carotid. The left vertebral artery may also arise from an intercostal artery. The vertebral artery may also have double origin, one from the subclavian and one from either the arch of the aorta or from the inferior thyroid artery.

The vertebral artery instead of entering into the foramen transversarium of the sixth cervical vertebra may pass through the foramen transversarium of any of the upper cervical vertebrae. It may enter the vertebral canal along with the second cervical nerve; before reaching the atlas it may divide into two branches, one enters the vertebral canal along with the second cervical nerve, and the other takes the usual course; the branches usually reunite again in the vertebral canal.

One of the vertebral arteries may end in a small terminal branch or its cranial continuation may be very small.

The inferior thyroid and the superior intercostal arteries may occasionally arise from the vertebral artery.

The **basilar artery** is formed by the union of the two vertebral arteries at the lower border of the pons opposite the median plane and extends up to the upper border of the pons where it ends by dividing into two posterior cerebral arteries. It is so named because it occupies its position at the base of the skull. It runs in the cisterna pontis on the ventral surface of the pons where it occupies a shallow median groove. At its origin it lies between the two abducent nerves and at its termination it lies between the two oculomotor nerves.

Development. The basilar artery develops from the fusion of the two enlarged spinal branches (pre-neural anastomoses) of the first cervical intersegmental artery.

Anomalies. The lumen of the basilar artery may be completely divided into two; a part of the basilar artery may be split into two. The basilar artery, instead of dividing into two posterior cerebral arteries, may be continued into a single posterior cerebral artery and the other posterior cerebral artery is supplied by the enlarged posterior communicating artery in such cases.

Branches:

(1) Anterior inferior cerebellar.
(2) Labyrinthine (Internal auditory).
(3) Pontine.
(4) Superior cerebellar.
(5) Posterior cerebral.

Anterior inferior cerebellar artery. It supplies the inferolateral aspect of the pons, adjoining portion of the medulla oblongata and the antero-inferior part of the cerebellum. It runs backwards and laterally from either side of the commencement of the basilar artery and lies in front of the sixth, seventh and the eighth cranial nerves and then passes to the internal acoustic meatus where it forms a loop. Then it runs over the antero-inferior aspect of the cerebellum and finally ends by anastomosing with the posterior inferior cerebellar artery.

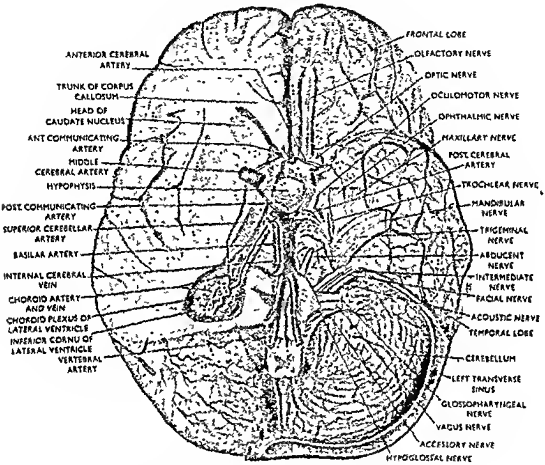


Fig. 610. The base of the brain showing the basilar artery.
With the kind permission from Lederle Laboratories—drawn by Mr. Paul Peck.

Labyrinthine (Internal auditory) artery. It may arise either from the basilar artery or from the antero-inferior cerebellar artery. It forms a long, slender branch which accompanies the seventh and the eighth nerves and enters into the internal acoustic meatus along with them. Then it enters into the internal ear and ends by supplying it.

Pontine branches. These are a number of small branches which arise from the front and the sides of the basilar artery and end by supplying the pons and the adjoining part of the brain.

Superior cerebellar arteries. They are two in number, one on each side and each arises from the side of the basilar artery just behind its terminal branches. It runs laterally below the oculomotor nerve which intervenes between it and the posterior cerebral artery and then it winds round the cerebral peduncle and finally, gains the superior surface of the cerebellum where it ramifies into branches and finally ends by anastomosing with the inferior cerebellar arteries.

Posterior cerebral arteries. They are the terminal branches of the basilar artery and are situated one on each side of the upper end of the pons. Each artery runs backwards and laterally in parallel with the superior cerebellar artery; the oculomotor nerve intervenes between the two arteries at their origin. It receives the posterior communicating branch of the internal carotid artery and then winds round the lateral aspects of the cerebral peduncles and finally reaches the tentorial surface of the cerebral hemisphere and ends by dividing into branches which supply the occipital and the temporal lobes. The branches of the posterior cerebral artery are arranged into central and cortical sets.

Central branches. These branches are arranged into three sets, posterolateral, posteromedial, the posterior.

The **posterolateral branches** supply the cerebral peduncles, the pineal, quadrigeminal and the medial geniculate bodies and the posterior part of the thalamus. They arise from the posterior cerebral artery as it winds round the cerebral peduncle.

The **posteromedial central branches** are several small arteries which arise from the posterior cerebral artery close to its origin from the basilar artery. These branches along with the similar branches from the posterior communicating artery pierce through the posterior perforated substance and end by supplying the lateral wall of the third ventricle, the globus pallidus of the lentiform nucleus and the ventral parts of the thalamus.

The **posterior choroid branches** supply the choroid plexuses of the third and the lateral ventricles and the fornix. They form about three or four branches, one or two of which pass laterally over the lateral geniculate body and gain access to the posterior part of the inferior horn of the lateral ventricle through the lower part of the chorioidal fissure, and the other branches enter into the tela chorioidea of the third ventricle through the upper part of the chorioidal fissure.

Cortical branches. The cortical branches are occipital, parieto-occipital and the temporal.

The occipital branches supply the cuneo-lingual gyri on the medial surface and the posterior part of the occipital lobe on the superolateral surface of the cerebral hemisphere.

The parieto-occipital branches supply the cuneus and the precuneus on the medial surface of the cerebral hemisphere.

The temporal branches supply the gyri on the inferior aspect of the temporal lobe of the cerebral hemisphere.

Thyrocervical trunk. It is a short arterial trunk arising from the front of the first portion of the subclavian artery close to the medial margin of the scalenus anterior and immediately after its origin it ends by dividing into inferior thyroid, transverse cervical and suprascapular branches.

Inferior Thyroid Artery. After its origin from the thyrocervical trunk it runs upwards in front of the medial margin of the scalenus anterior for a short distance and then passes medially to cross in front of the vertebral vessels and behind the carotid sheath and the middle cervical sympathetic ganglion. Then it descends downwards on the longus cervicis muscle to reach the lower part of the lateral lobe of the thyroid gland. Immediately before it reaches the thyroid gland it usually lies behind the recurrent laryngeal nerve but the nerve may cross in front of it or may lie in between its branches.

Branches:

(1) Muscular.	(4) Tracheal.
(2) Ascending cervical.	(5) Oesophageal.
(3) Inferior laryngeal.	(6) Glandular.

Muscular branches. They supply the inferior belly of the omohyoid, sterno-

hyoid, sternothyroid, longus cervicis and the inferior constrictor muscle of the pharynx.

Ascending cervical. It arises from the inferior thyroid artery as it ascends upwards in front of the transverse processes of the cervical vertebrae and lies in between the scalenus anterior and the longus capitis muscle. In its course upwards it runs parallel to the phrenic nerve and supplies muscular and spinal branches. It ends by anastomosing with the vertebral, occipital, ascending pharyngeal and then deep cervical arteries.

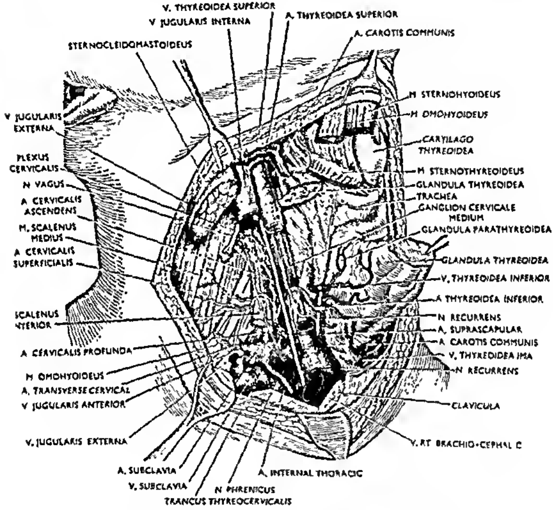


Fig. 611. The great vessels of the neck. With the kind permission from Lederle Laboratories—drawn by Mr. Paul Peck.

Inferior laryngeal artery. It accompanies the recurrent laryngeal nerve and nters the larynx deep to the lower border of the inferior constrictor muscle of the harynx. In its course it supplies the muscles and the mucous membrane of the arynx and ends by anastomosing with the fellow of its opposite side and also with he superior thyroid artery.

Tracheal branches. They are distributed to the trachea and anastomose below vith the bronchial artery.

Oesophageal branches. They are distributed to the oesophagus and end by anastomosing with the oesophageal branches of the descending thoracic aorta.

Glandular branches. The glandular branches consist of *ascending* and nferior branches which supply the postero-inferior part of the thyroid gland.

end by anastomosing with the fellow of the opposite side and with the superior thyroid artery. The ascending branch also supplies the parathyroid gland.

Transverse Cervical Artery. After its origin from the inferior thyroid artery it passes transversely across the floor of the posterior triangle to reach the anterior margin of the levator scapulae where it divides into superficial and deep branches. In its course it crosses in front of the scalenus anterior, the phrenic nerve and the brachial plexus of nerves and is placed at a higher level than the suprascapular artery. It is covered by the skin, superficial fascia, platysma and the deep fascia and to a small extent by the sternomastoid.

The *superficial branch* ascends upwards under cover of the anterior part of the trapezius and ends by anastomosing with the superficial branch of the ramus descendens of the occipital artery. In its course it supplies the adjacent muscles and the deep cervical lymph glands.

The *deep branch* runs under cover of the levator scapulae to reach the superior angle of the scapula from where it descends along its vertebral border under cover of the rhomboids and reaches its inferior angle. In its course it anastomoses with the suprascapular, subscapular and the posterior intercostal arteries. It supplies the trapezius, latissimus dorsi and the rhomboids.

Suprascapular Artery. It lies at a lower level than the transverse cervical artery and runs downwards and laterally behind the sternocleidomastoid and the external jugular vein and in front of the scalenus anterior, phrenic nerve and the brachial plexus of nerves. Then it runs transversely across the upper part of the posterior surface of the clavicle and crossing the terminal portion of the subclavian vessels it reaches the lateral end of the superior border of the scapula under cover of the trapezius and enters the supraspinous fossa by passing over the suprascapular ligament which separates it from the suprascapular nerve. In this situation it lies deep to the supraspinatus and then winds round the spinoglenoid notch deep to the spinoglenoid ligament and reaches the infraspinous fossa. In the infraspinous fossa it anastomoses with the scapular circumflex artery and the deep branch of the transverse cervical artery. In the supraspinous fossa it also anastomoses with preceding arteries. As it crosses over the suprascapular ligament it supplies a branch to the subscapular fossa where it anastomoses with the subscapular artery and the deep branch of the transverse cervical artery. Besides the above branches it also provides acromial and sternal branches. The acromial branch becomes subcutaneous by piercing the trapezius and supplies the skin over the acromion process and ends by anastomosing with the acromial branch of the acromiothoracic artery. The sternal branch ends by supplying the skin over the sternal end of the clavicle.

Costocervical trunk. The costocervical trunk arises from the posterior aspect of the second portion of the subclavian artery on the right side. On the left side the costocervical trunk arises from the first part of the subclavian artery. It runs backwards over the cervical dome of the pleura and then descends to the neck of the first rib where it ends by dividing into superior intercostal and deep cervical arteries.

Superior intercostal artery. The superior intercostal artery descends downwards in front of the necks of the first and the second ribs and then anastomoses with the third posterior intercostal artery. In its course downwards, it, at first, lies medial to the anterior primary ramus of the first thoracic nerve, and then crosses in front of it and lies on the lateral side of the first thoracic sympathetic ganglion. In the first intercostal space it gives out the first posterior intercostal artery and in the second space it joins with a branch from the third posterior intercostal artery and gives out the second posterior intercostal artery.

Deep cervical artery. It runs backwards above the eighth cervical nerve and between the transverse process of the seventh cervical vertebra and the neck of the first rib and then ascends upwards between the semispinalis capitis et cervicis

upto the level of the second cervical vertebra and finally ends by anastomosing with the descending branch of the deep division of the occipital artery and with the branches of the vertebral artery. In its course it supplies the adjacent muscles.

Internal thoracic (mammary) artery. *Course.* The internal thoracic artery arises from the inferior aspect of the first portion of the subclavian artery. From its origin it passes downwards, forwards and medially and enters the thorax behind the sternoclavicular articulation. In the thorax it descends vertically downwards behind the cartilages of the upper ribs and lying at a distance of about half an inch lateral to the sternum. Reacting the lower border of the sixth intercostal space it ends by dividing into musculophrenic and superior epigastric arteries.

Relations. Anteriorly it is covered by pectoralis major muscle, cartilages of the upper six ribs, external intercostal membranes and the internal intercostal muscles. As it enters the thorax it passes behind the sternal end of the clavicle, the internal jugular and innominate veins and the first costal cartilage and is crossed by the phrenic nerve from lateral to medial side—the nerve usually passing in front of the artery. In the thorax it is crossed transversely by the anterior cutaneous nerve of the upper six intercostal spaces.

Posteriorly and below, it is separated from the lungs and pleura by the sternocostalis muscle and higher up by a thick fascia.

On each side, it is accompanied by a vein and some lymphatics, opposite the level of the third costal cartilage the veins unite to form a single vein which lies on the medial side of the artery and opens into the innominate vein.

Branches:

(1) Anterior intercostal.
(2) Perforating.
(3) Pericardiaco-phrenic.
(4) Sternal.
(5) Pericardial.
(6) Thymic.
(7) Mediastinal.
(8) Superior epigastric.
(9) Musculophrenic.

Anterior intercostal. The anterior intercostal branches of the internal mammary artery supply upper six intercostal spaces. In each intercostal space there are two branches—one passes laterally along the upper border of the lower rib while the other passes along the lower border of the upper rib. They end by anastomosing with the posterior intercostal arteries. At first they lie between the pleura and the intercostal muscles and then between the intercostalis intimi and the intercostalis internus.

Perforating. The perforating branches will be found in the upper six intercostal spaces and each pierces the intercostal muscles, and accompanying the anterior cutaneous nerve pierces the pectoralis major and the deep fascia. In case of female the branches from the second, third and fourth spaces are comparatively large and supply the mammary gland.

Pericardiaco-phrenic. It is a long slender artery which accompanies the phrenic nerve and descends downwards in between the pleura and the pericardium to reach the diaphragm where it ends by anastomosing with the musculophrenic and the phrenic arteries. It supplies the pleura, pericardium and the diaphragm.

Sternal. They are small branches which supply the sternocostalis muscle and the back of the sternum.

Pericardial. These are small branches which supply the anterior aspect of the pericardium.

Thymic. It supplies the remains of the thymus gland.

Mediastinal. These are small branches which are distributed to the mediastinum.

Superior epigastric. It is one of the terminal branches of the internal mammary artery and descends downwards into the rectus sheath through the gap between

the xiphoid slip and the costal slip (that on the seventh costal cartilage) of the diaphragm. It at first lies on the sternocostalis and then on the transversus abdominis and in the rectus sheath, it passes downwards through the fibres of the rectus abdominis and ends by anastomosing with the inferior epigastric branch of the external iliac artery. In its course in the rectus sheath it provides branches which pierce the muscle and fascia and are distributed to the anterior abdominal wall. It provides a branch in front of the xiphoid process which anastomoses with the fellow of its opposite side. On the right side a small branch accompanies the falciform ligament of the liver and ends by anastomosing with the hepatic artery. It also supplies a few twigs to the diaphragm.

Musculophrenic. It is the lateral terminal branch of the internal thoracic artery and arises from the same opposite the sixth intercostal space. It runs obliquely downwards and laterally behind the cartilages of the seventh, eighth and ninth ribs and then pierces the diaphragm muscle. Before it pierces the diaphragm it gives out anterior intercostal branches for the seventh, eighth and ninth interspaces and is distributed in the same manner as the other anterior intercostal arteries. In its course through the diaphragm it anastomoses with the phrenic, lower two posterior intercostal and with the ascending branch of the deep circumflex iliac artery.

Axillary artery. *Origin.* It is the direct continuation of the subclavian artery.

Extent. It begins from the outer border of the first rib and extends to the lower border of the insertion of the teres major.

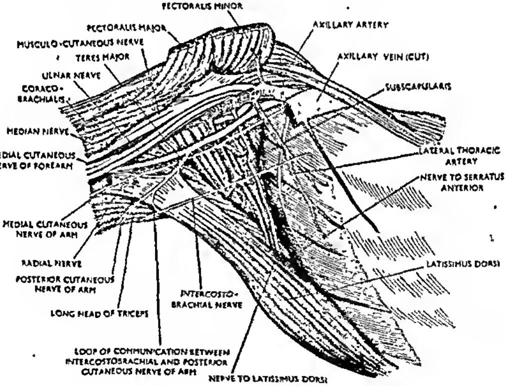


Fig. 612. The brachial plexus of nerves with the axillary vessels. The axillary vein has been partly removed.
From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

Divisions. The pectoralis minor muscle crosses in front of it and divides it into three parts—first part lying proximal to the pectoralis minor, the second part lying behind the pectoralis minor and the third part lying distal to it.

First part of the axillary artery. The first portion of the axillary artery extends from the outer border of the first rib to the upper border of the pectoralis minor muscle.

Anterior relations. It is covered in front by the skin, superficial fascia, the supraclavicular nerves, deep fascia, clavicular fibres of the pectoralis major muscle, clavipectoral fascia, the loop of communication between the lateral and medial pectoral nerves, and the structures piercing the clavipectoral fascia, *i.e.*, the cephalic vein, acromio-thoracic vessels and the lateral pectoral nerve.

Posterior relations. It lies upon the first intercostal space and the first digitation of the serratus anterior and is in relation to the medial cord of the brachial plexus and the medial pectoral nerve.

Laterally. The lateral and the posterior cords of the brachial plexus lie on its lateral side.

Medially. It is related to the axillary vein.

Second portion of the axillary artery. The second portion of the axillary artery is more deeply seated and corresponds to that portion which lies under cover of the pectoralis minor muscle.

Relations: Anteriorly. It is related to the skin, superficial fascia, deep fascia, and the pectoralis major et minor muscles.

Posteriorly. It is related to the posterior cord of the brachial plexus and the subscapularis muscle.

Laterally. It is related to the lateral cord of the brachial plexus and medially to the medial cord of the brachial plexus and the axillary vein.

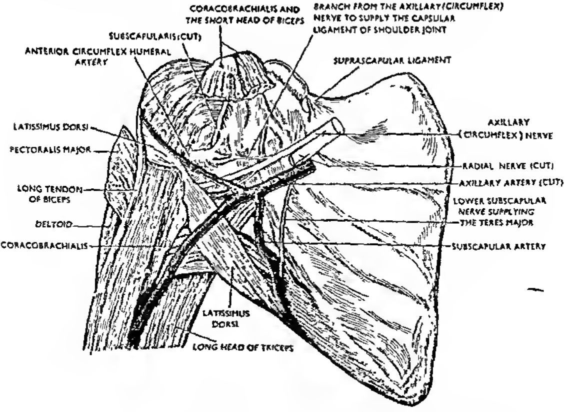


Fig. 613. The ventral aspect of the humero-scapular region. The subscapularis muscle, veins and some of the branches of the brachial plexus of nerves have been removed.

From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

Third part of the axillary artery. It begins from the lower border of the pectoralis minor as a continuation of its second part and descends successively on the subscapularis, latissimus dorsi and the teres major and reaching the lower border of the latter it is continued downwards as the brachial artery.

Its lower part is superficial being covered only by the skin and the fascia but its *upper part* is overlapped by the pectoralis major. *Laterally* it is related to the lateral root of the median, musculo-cutaneous nerve and the coracobrachialis muscle. *Medially* it is related to the axillary vein and intervening between the two are the medial cutaneous nerve of the forearm anteriorly and the ulnar nerve posteriorly. *Posteriorly* it is related to the muscles on which it descends and to the radial and the circumflex nerves.

Branches:

(1) Superior thoracic—From the first part.
(2) Thoraco-acromial (Acromiothoracic) } From the second part.
(3) Lateral thoracic. }
(4) Anterior humeral circumflex. }
(5) Posterior humeral circumflex. } From the third part.
(6) Subscapular. }

Development. The axillary artery is the proximal portion of the axial artery of the upper limb and is in direct continuation of the seventh intersegmental artery.

Anomalies. The anomalies affecting the axillary artery are mostly confined to its branches; its course or origin does not vary much but it may have abnormal relation with the axillary arch when present; the axillary arch connects the latissimus dorsi with the pectoralis major and may be either fleshy or tendinous; in its course the arch passes superficial to the distal part of the axillary artery.

The subscapular, anterior and posterior circumflex humeral arteries and the arteria profunda brachii may arise by a common stem; when this common stem is present the branches of the brachial plexus of nerves surround it instead of the axillary artery proper. The axillary artery may occasionally divide into ulnar and radial arteries; the posterior circumflex humeral artery may occasionally arise from the arteria profunda brachii and runs backwards behind the teres major instead of passing through the quadrangular space. The common interosseous artery may also arise from the axillary artery.

Superior thoracic artery. It arises from the first part of the axillary artery opposite the lower border of the subclavius and descends on the thoracic wall along the upper border of the pectoralis minor. It supplies the adjacent muscles and ends by anastomosing with the branches of the internal thoracic and intercostal arteries.

Thoraco-acromial (Acromiothoracic) *artery.* It is a short trunk which arises from the anterior aspect of the second portion of the axillary artery and after piercing the clavipectoral fascia at once splits up into four branches, pectoral, deltoid, clavicular and the acromial. The *pectoral branch* runs downwards in between the pectoralis major et minor, supplies these muscles and the mammary gland and then ends by anastomosing with the anterior intercostal branches of the internal thoracic artery and the lateral thoracic artery. The *deltoid branch* often arises by a common trunk with the acromial branch and passes laterally in front of the insertion of the pectoralis minor and then accompanying the cephalic vein it runs in the groove between the deltoid and the pectoralis major and ends by supplying these muscles. The *clavicular branch* passes upwards and medially towards the sternal end of the clavicle behind the clavicular fibres of the pectoralis major and ends by supplying the sternoclavicular articulation and the subclavius muscle. The *acromial branch* usually arises by a common trunk with the deltoid branch and passes upwards and laterally by crossing in front of the coracoid process and lies under cover of the deltoid. Finally it pierces the deltoid and reaches the acromial process of the scapula where it anastomoses with the transverse cervical, posterior humeral circumflex and the suprascapular arteries.

Lateral thoracic artery. It arises from the second part of the axillary artery and descends on the thoracic wall along the lower border of the pectoralis minor and supplies the adjacent muscles. In the female it gives out the *external mammary* branch which supplies the breast. In its course it anastomoses with the internal thoracic

(mammary), subscapular, intercostal arteries and with the pectoral branch of the thoraco-acromial (acromiothoracic) artery.

N.B. In case of ligature of the first part of the axillary artery collateral circulation will be maintained as in the ligature of the third part of the subclavian artery. The following would be the mode of circulation:

(1) Transverse cervical and suprascapular arteries from the thyrocervical trunk of the subclavian artery anastomose with the subscapular branch of the third part of the axillary artery.

(2) Internal thoracic (mammary) branch of the subclavian artery anastomoses with the lateral thoracic, superior thoracic and subscapular arteries.

(3) A few small branches from the subclavian artery pass through the axilla and anastomose with the axillary artery or some of its branches.

In case of the ligature of the second part of the axillary artery between the origins of the thoraco acromial (acromiothoracic) and the lateral thoracic arteries the collateral circulation will be maintained by the anastomosis formed between the subscapular artery, and the suprascapular and transverse cervical arteries, and between the lateral thoracic and the internal thoracic (mammary) and intercostal arteries.

In case of ligature of the third part of the *axillary artery* below the subscapular artery the collateral circulation will be maintained through the subscapular and the anterior and posterior humeral circumflex arteries anastomosing with the branches of the arteria profunda brachii.

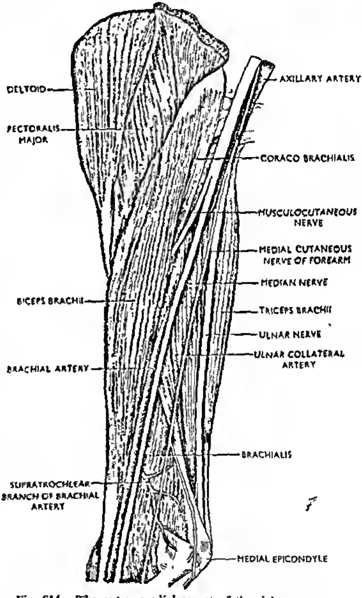


Fig. 614. The antero-medial aspect of the right arm to show the brachial artery. From the dissection hall, N.R. Sircar Medical College, Cal; with the kind permision from the Prof. of Anatomy.

Anterior humeral circumflex artey. It arises from the lateral side of the third part of the axillary artery at the lower border of the subscapularis and then passes to the surgical neck of the humerus behind the common tendon of coracobrachialis and the short head of the biceps brachii. Opposite the intertubercular sulcus it

provides an ascending branch which supplies the shoulder joint. It then passes forwards under cover of the deltoid muscle and ends by anastomosing with the posterior humeral circumflex artery.

Posterior humeral circumflex artery. It is larger than the preceding artery and arises from the third part of the axillary artery at the lower border of the subscapularis muscle. It passes backwards in the quadrangular space in company with the axillary (circumflex) nerve and winds round the surgical neck of the humerus and ends by anastomosing with the anterior humeral circumflex artery. In its course it supplies the shoulder joint and the adjacent muscles and anastomoses with the subscapular and the thoraco-acromial (acromiothoracic) arteries.

Subscapular artery. It arises from the lower part of the third part of the axillary artery opposite the lower border of the subscapularis and as it descends downwards to the intermuscular gap between the subscapularis and the teres major et latissimus it crosses in front of the axillary (circumflex) nerve and behind the radial nerve and then divides into three branches—one passes to the subscapularis muscle, one to the latissimus dorsi and the other through the triangular space as the *scapular circumflex artery* which passes to the infraspinous fossa. Its terminal twig passes to the inferior angle of the scapula where it anastomoses with the lateral thoracic, intercostal and the deep branch of the transverse cervical arteries. In the lower part of its course it is accompanied by the nerve to the latissimus dorsi.

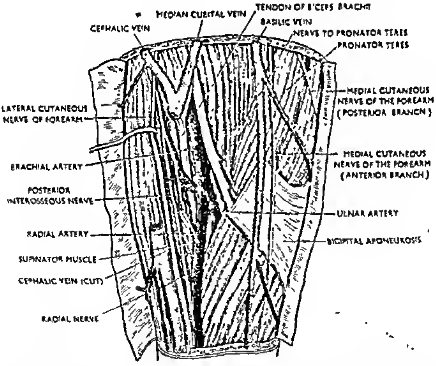


Fig. 615. The right cubital fossa to show the relations of the terminal portion of the brachial artery. From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

Brachial artery. *course.* The brachial artery is the direct continuation of the axillary artery and begins from the lower border of the teres major and ends by dividing into ulnar and radial arteries in the cubital fossa about half an inch below the bend of the elbow joint. At first it lies on the medial side of the arm but from the lower part of the arm it gradually inclines forwards to reach the front of the elbow joint where it is placed midway between the two humeral epicondyles.

Relations. The artery is superficial throughout its entire extent and is covered superficially by the skin and the superficial and the deep fasciae. It lies successively upon the long and the medial heads of the triceps, insertion of the coracobrachialis and the brachialis muscle. It is in direct contact with all the muscles enumerated above except the long head of the triceps which is separated from it by the radial nerve and the profunda vessels. The median nerve crosses either superficial or deep to the vessels from lateral to the medial side opposite the insertion of the coracobrachialis. *Laterally and above,* it is related to the median nerve and the biceps brachii muscle; *laterally and below,* it is related to the biceps brachii. *Medially and above,* it is related to the basilic vein but is separated from it by the medial cutaneous nerve of the forearm in front and the ulnar nerve behind. *Medially and below,* it is related to the median nerve and is separated from the basilic vein by the deep fascia. *In the cubital fossa* it lies in between the tendon of the biceps laterally and the median nerve medially, and is covered by the bicipital aponeurosis which separates it from the median cubital vein. It gives out the following branches :

Branches :

(1) Arteria profunda brachii.
(2) Superior ulnar collateral.
(3) Nutrient.
(4) Inferior ulnar collateral (supratrochlear).
(5) Muscular.
(6) Ulnar.
(7) Radial.

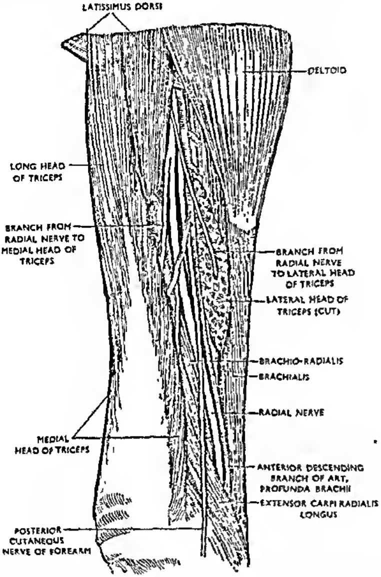
Development. The brachial artery represents the axial artery of the upper limb and is continuous with the seventh intersegmental artery.

Anomalies. The brachial artery may arise as two branches which reunite near the bend of the elbow. It may terminate in the usual position into three branches, ulnar, radial and common interosseous, instead of usual two, ulnar and radial. Alternatively it may also terminate to the radial and the common interosseous arteries. The brachial artery may divide high up in the arm, more often in the proximal third of the arm. The brachial artery may occasionally be buried in the substance of the pronator teres near its termination, and higher up in the arm, it may be concealed by the supracondylar process and the fibrous band that extends from it to the medial epicondyle. In case of high division, the radial artery may be superficial lying beneath the skin in the forearm and under the deep fascia in the arm.

Arteria profunda brachii. The arteria profunda brachii is a short stout branch from the brachial artery arising from it about one inch below the lower border of the teres major muscle. It runs medially and backwards between the long and the medial heads of the triceps and accompanying the radial nerve reaches the spiral groove where it is overlapped by the lateral head of the triceps muscle. In the spiral groove it breaks up into two main branches—*anterior* and *posterior descending*, and several smaller branches. The *anterior descending branch* accompanying the radial nerve pierces the lateral intermuscular septum and then descends in front of it to reach the front of the lateral epicondyle where it ends by anastomosing with the radial recurrent branch of radial artery. The *posterior descending branch* descends on the back of the lateral intermuscular septum to reach the back of the lateral epicondyle where it ends by anastomosing with the interosseous recurrent branch of the posterior interosseous artery. The smaller branches of the arteria profunda brachii are the muscular, nutrient and ascending. The *ascending branch* runs upwards and joins in the cruciate anastomosis around the surgical neck of the humerus.

Superior ulnar collateral. It arises from the brachial artery opposite the insertion of the coracobrachialis and accompanying the ulnar nerve it pierces the medial intermuscular septum and then descends with the same nerve through the posterior compartment of the arm to reach the interval between the medial epicondyle and the olecranon. Then under cover of the flexor carpi ulnaris it ends by anastomosing with the posterior ulnar recurrent and with the posterior branch of the inferior ulnar collateral (supratrochlear) artery. Sometime it also provides an anterior

branch which anastomoses with the anterior ulnar recurrent artery in front of the medial epicondyle.



ig. 616. The postero-lateral aspect of the right arm. The spiral groove is exposed after removing the lateral head of triceps.
From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

Nutrient artery. It arises from the medial aspect of the brachial artery below ıe insertion of the coracobrachialis and soon enters into the nutrient canal through ıe nutrient foramen of the humerus. It is usually very tortuous before it enters ıto the nutrient canal and this tortuosity prevents it from being torn during active ıuscular movement and also prevents the blood pressure of the artery to be altered uring muscular movement.

Inferior ulnar collateral (supratrochlear) *artery.* It arises from the brachial rtery about two inches above the elbow joint and runs downwards and medially ı front of the brachialis and behind the median nerve and then divides into anter- ır and posterior branches. The posterior branch is larger than the anterior and it

reaches the posterior compartment by piercing the medial intermuscular septum and divides into two branches. One branch passes laterally above the olecranon fossa and anastomoses with the posterior descending branch of the arteria profunda brachii to form an arterial arch above the olecranon fossa, and the other descends behind the medial epicondyle where it anastomoses with the ulnar collateral and the posterior ulnar recurrent arteries. The anterior branch descends in front of the medial epicondyle and ends by anastomosing with the anterior ulnar recurrent artery.

Muscular branches. Three to four muscular branches arise from the brachial artery in the arm and they supply the muscles of the anterior compartment of the arm namely, the brachialis, biceps brachii and the coracobrachialis.

N. B. In case of ligature of the brachial artery below the origin of the arteria profunda brachii, collateral circulation is efficiently maintained through the anastomosis around the elbow joint.

Anastomosis around the elbow joint. Seven arteries take part in the anastomosis around the elbow joint and of these three are descending namely, arteria profunda brachii, inferior ulnar collateral (supratrochlear) and the superior ulnar collateral, and four are ascending, *viz.*, anterior ulnar recurrent, posterior ulnar recurrent, radial recurrent and the interosseous recurrent. The anastomosis usually takes place in front of and behind the medial and the lateral epicondyles and also around the olecranon fossa and accordingly they are grouped as follows :

(1) *In front of the medial epicondyle.* Anterior ulnar recurrent branch of the ulnar artery anastomoses with the anterior branches of the superior and inferior ulnar collateral arteries.

(2) *Behind the medial epicondyle.* Posterior ulnar recurrent branch of the ulnar artery anastomoses with the posterior branches of the superior and inferior ulnar collateral branches of the brachial artery.

(3) *In front of the lateral epicondyle.* Radial recurrent branch of the radial artery anastomoses with the anterior descending branch of the arteria profunda brachii.

(4) *Behind the lateral epicondyle.* Interosseous recurrent branch of the posterior interosseous artery anastomoses with the posterior descending branch of the arteria profunda brachii.

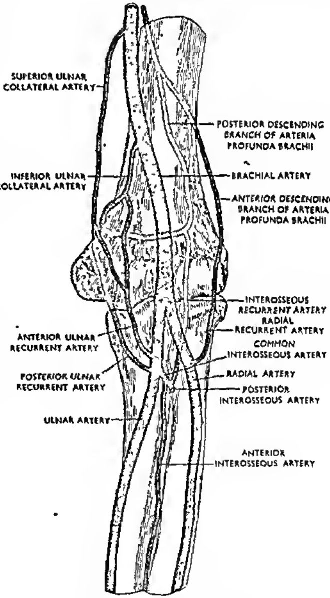


Fig. 617. The anastomosis around the elbow joint.

(5) *Around the olecranon fossa.* Inferior ulnar collateral (supratrochlear) artery anastomoses with the posterior descending branch of the arteria profunda brachii and with the interosseous recurrent and the posterior ulnar recurrent arteries.

Radial artery. The radial artery is the smaller terminal branch of the brachial artery and arises from it in the cubital fossa about 1 cm. below the bend of the elbow and opposite the neck of the radius. After its origin it traverses through the lateral aspect of the forearm from the lower end of which it takes a turn laterally and backwards to pass over the lateral aspect of the carpus; and finally it curves

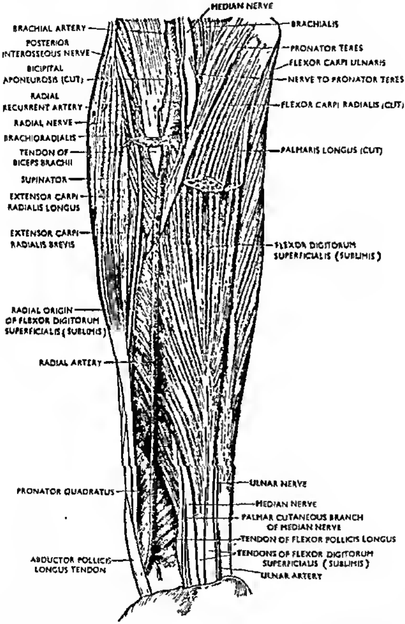


Fig. 610. The front of the right forearm. The flexor carpi radialis and the palmaris longus have been partially removed. Note the structures on which the radial artery lies posteriorly. From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

medially to enter into the palm where it anastomoses with the deep branch of the ulnar artery to complete the formation of the deep palmar arch. Thus the radial artery may be discussed under three heads, radial artery in the forearm, in the wrist and in the palm.

Radial artery in the forearm. It at first passes laterally and downwards and then descends vertically downwards to reach the interval between the prominent anterior margin of the lower part of the radius and the tendon of the flexor carpi radialis. Then it curves laterally behind the tendons of the abductor pollicis longus and the extensor pollicis brevis to enter into the wrist.

Relations. In the forearm, *posteriorly* it lies successively upon the tendon of the biceps brachii, supinator, insertion of the pronator teres, radial origin of the flexor digitorum superficialis (sublimis), flexor pollicis longus, pronator quadratus and the lower end of the radius. *Anteriorly* in the upper-third of the forearm it is overlapped by the brachioradialis but in the lower two-thirds it is covered by the skin, superficial fascia and the deep fascia. Above the wrist joint the terminal part of the lateral cutaneous nerve of the forearm lies in front of it. *Laterally*, throughout the whole length it is related to the brachioradialis. The radial nerve at first is separated from its lateral side by a considerable distance but opposite the middle-third of the forearm it forms immediate lateral relation to it. About 7 cm. above the wrist joint the radial nerve quits the artery and passes to the back of the forearm under the tendon of the brachioradialis. *Medially* it is related to the pronator teres in the upper-third and to the flexor carpi radialis in its lower-third.

In the forearm it gives out four branches, radial recurrent, muscular, superficial palmar and the anterior carpal.

(*a*) *Radial recurrent artery.* It arises from the lateral side of the radial artery and forming an arch with a convexity downwards and laterally it ascends upwards under cover of the medial margin of the brachioradialis to reach the front of the lateral epicondyle where it ends by anastomosing with the anterior descending branch of the arteria profunda brachii.

(*b*) *Muscular.* Numerous muscular branches arise from the artery and supply the adjacent muscles.

(*c*) *Palmar* (anterior) *carpal.* It is a small artery which arises from the medial side of the radial artery below the lower border of the pronator quadratus and passes medially beneath the flexor tendons to join in the anterior carpal anastomosis.

(*d*) *Superficial palmar.* It arises from the radial artery below the palmar (anterior) carpal artery and descends downwards either superficial to the thenar muscles or passes through them to the palm where it anastomoses with the ulnar artery to complete the superficial palmar arch. It may end by supplying the thenar muscles and may not join the ulnar artery to form the arch.

Radial artery in the wrist: *Course.* From opposite the front of the lower end of the radius, the radial artery curves backwards behind the abductor pollicis longus and extensor pollicis brevis and reaches the back of the proximal part of the first intermetacarpal space where it dips in between the two heads of the first dorsal interosseous muscle and enters into the palm of the hand.

Relations. As it curves backwards it lies in between the lateral ligament of the wrist joint and the tendons of the abductor pollicis longus et extensor pollicis brevis. In the anatomical snuff-box it lies on the scaphoid and the trapezium and is crossed by the origin of the cephalic vein, digital branches of the radial nerve to the thumb and the extensor pollicis longus tendon. The anatomical snuff-box is bounded in front by the abductor pollicis longus et extensor pollicis brevis and medially by the extensor pollicis longus. The floor is formed by the lateral ligament of the wrist joint connecting scaphoid and the trapezium. It is superficial in this situation being covered only by the skin and the fasciae.

Branches of the radial artery in the wrist:

(1) Dorsal (posterior) carpal.
(2) First dorsal metacarpal.

Dorsal (posterior) *carpal artery*. It arises from the radial artery in the wrist in the anatomical 'snuff-box' deep to the extensor tendons. After its origin it passes medially across the dorsum of the carpus deep to the extensor tendons of the medial four digits and finally reaching the medial extremity of the carpus it ends by anastomosing with the dorsal carpal branch of the ulnar artery to form the *dorsal carpal arch*. It is also joined by the anterior and posterior interosseous arteries from above.

The *dorsal carpal arch* gives origin to the medial *three dorsal metacarpal arteries* (the first dorsal metacarpal artery arises directly from the radial artery), *i.e.*, the second, third and fourth dorsal metacarpal arteries. Each of these dorsal metacarpal arteries descends downwards on the corresponding dorsal interosseous muscle and reaching the distal end of the corresponding intermetacarpal space each divides into *two dorsal digital branches* which supply the contiguous sides of the digits. Thus the second dorsal metacarpal artery supplies the contiguous sides of the index and middle fingers, the third supplying the middle and ring fingers while the fourth one supplies the ring and the little fingers. Each dorsal digital artery ends distally by anastomosing with the palmar digital artery.

Each dorsal metacarpal artery is connected with the deep palmar arch at its proximal end by the *proximal perforating artery* from the deep palmar arch; at its distal end, just before its bifurcation into two dorsal digital arteries it communicates with the corresponding palmar digital artery from the superficial palmar arch through the *distal perforating artery*.

First dorsal metacarpal artery. It lies on the first dorsal interosseous muscle and arises from the radial artery just before it enters into the palm of the hand between the two heads of the first dorsal interosseous muscle. After a short course it divides into two collateral branches which supply the contiguous sides of the thumb and index fingers.

Radial artery in the hand. The radial artery enters the palm between the two heads of the first dorsal interosseous muscle and then passes transversely across the palm deep to the adductor pollicis muscle and finally reaching the base of the fifth metacarpal bone it ends by anastomosing with the deep branch of the ulnar artery and completes the deep palmar arch.

Branches:

(1) Arteria princeps pollicis.
(2) Arteria radialis indicis.

Arteria princeps pollicis. It arises from the radial artery as the latter turns medially to enter into the palm of the hand. It descends downwards on the palmar aspect of the first metacarpal bone lateral to the first palmar interosseous muscle lying deep to the oblique head of the adductor pollicis. Reaching the base of the proximal phalanx it divides into two branches which supply the palmar aspect of the thumb.

Arteria radialis indicis. It arises from the radial artery as it enters into the palm. It may, however, take its origin from the arteria princeps pollicis. It reaches the radial side of the index finger by passing deep to the transverse head of the adductor pollicis. At the distal end of the index finger it ends by anastomosing with the palmar digital artery supplying the medial side of the index finger.

Deep palmar arch. The deep palmar arch is formed by the anastomosis of the terminal portion of the radial artery and the deep branch of the ulnar artery. It is about $1\frac{1}{2}$ inches long and extends from the base of the second metacarpal bone to the base of the fifth metacarpal bone. It lies in front of the interosseous muscles

and the metacarpal bones close to their bases. It is covered by the skin, superficial fascia, palmar aponeurosis, superficial palmar arch, flexor tendons and the adductor pollicis muscle.

Branches:

(1) *Palmar metacarpal.* They are three in number; they run distally in front of the interosseous muscle of the second, third and fourth intermetacarpal spaces and end by joining with the digital artery from the superficial palmar arch.

(2) *Perforating branches.* They are three in number; they pass backwards

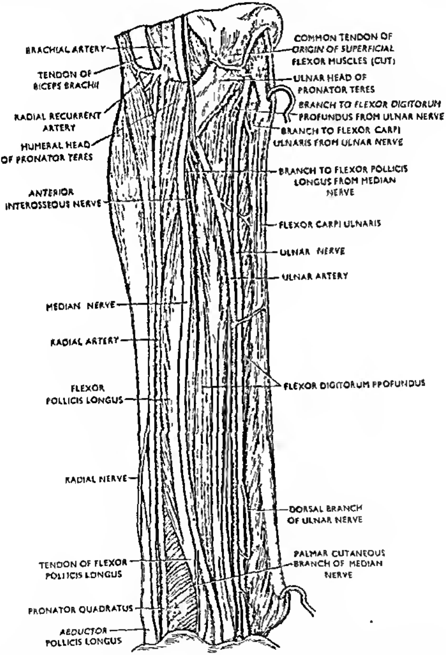


Fig. 619. The front of the right forearm. The humeral head of the pronator teres and other superficial flexors have been removed. Note the relations of the main vessels and nerves of the forearm. From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

between the two heads of the dorsal interosseous muscles of the second, third and fourth interspaces and end by anastomosing with the dorsal metacarpal arteries.

(3) *Recurrent.* The recurrent branch ascends upwards to end into the carpal anastomosis.

Development. The *primary radial artery* arises from the axial artery in the arm whereas the *definitive radial artery* arises from the axial artery at the bend of the elbow. Subsequently, the primary radial artery joins with the definitive radial artery. At a later date, the primary radial artery retrogresses completely but occasionally it may persist so as to account for the origin of the radial artery from the brachial in the arm in some cases

Anomalies. The radial artery may be absent, its place being taken over by the branches of the ulnar artery or its interosseous branches. It might have higher origin in the arm. In the forearm it may be superficial to the deep fascia instead of deep to it and in the wrist it may cross superficial to the extensor tendons instead of deep to them. The arteria princeps pollicis and radialis indicis branches may not arise from the radial but they may arise from either the superficial palmar arch or from the radial dorsal digital artery of the index finger. Its superficial palmar branch may terminate by supplying the thenar muscles and may fail to join the superficial palmar arch.

The deep palmar arch may be absent in rare cases, and when it is absent, its branches are replaced by either the superficial palmar arch, the volar (anterior) carpal arch or by the proximal perforating branches of the dorsal metacarpal arteries.

Ulnar artery. *Origin and Course in the forearm.* It is the larger terminal branch of the brachial artery and begins opposite the neck of the radius half an inch below the elbow joint. At first it runs obliquely beneath the superficial flexor muscles to reach the medial side of the forearm and then it descends vertically downwards to the lateral side of the pisiform bone and enters the palm superficial to the flexor retinaculum and then ends by dividing into superficial and deep branches.

Relations in the forearm—Anteriorly. In the cubital fossa at its origin it is superficial being covered only by skin, superficial and deep fasciae. Then as it passes obliquely to the medial side of the forearm it passes behind the pronator teres, flexor carpi radialis, palmaris longus and flexor digitorum superficialis (sublimis). During the rest of its course it is overlapped by the flexor carpi ulnaris muscle. As it passes deep to the ulnar head of the pronator teres it is crossed by the median nerve but is separated from it by the ulnar head of the pronator teres.

Posteriorly. It lies upon the brachialis in the cubital fossa and on the flexor digitorum profundus during the rest of its course in the forearm.

Laterally. It is related to the flexor digitorum superficialis (sublimis).

Medially. It is related to the flexor carpi ulnaris throughout its whole extent. The ulnar nerve lies medial to it opposite the lower two-thirds of the forearm only.

Branches in the forearm:

(1) Anterior ulnar recurrent.
(2) Posterior ulnar recurrent.
(3) Common interosseous.
(4) Muscular.

Anterior ulnar recurrent artery. It arises from the ulnar artery in the cubital fossa and ascends upwards between the brachialis and the pronator teres to the front of the medial epicondyle where it ends by anastomosing with the branches of the superior and inferior ulnar collateral arteries.

Posterior ulnar recurrent artery. It arises from the ulnar artery as it passes medially deep to the superficial flexor muscles and runs upwards, medially and backwards to the back of the medial epicondyle of the humerus. In its course it lies between the flexor digitorum profundus posteriorly and the flexor digitorum superficialis anteriorly and enters the groove on the back of the medial epicondyle by passing between the two heads of the flexor carpi ulnaris and lies in close contact with the ulnar nerve. It ends by anastomosing with the superior and inferior ulnar collateral arteries.

Common interosseous artery. It is a short branch from the ulnar artery and takes its origin a little below the radial tuberosity. It passes backwards to reach the in-

peritoneum and crosses in front of the right ureter, right testicular or ovarian vessels and the right psoas major muscle.

The inferior branch of the ileocolic artery gives out *colic, anterior* and *posterior caecal, ileal* and *appendicular* branches. The colic branch supplies the ascending colon. The anterior and posterior caecal branches supply the corresponding aspect of the caecum. The ileal branch supplies the terminal portion of the ileum. The appendicular branch runs downwards and to the right behind the terminal portion of the ileum and reaches the mesentery of the vermiform appendix. It then runs in the free border of the mesentery of the vermiform appendix and reaches as far as its tip. It is an end artery and does not anastomose with any other arteries.

(*d*) The **right colic artery** arises from the middle of the right concave margin of the superior mesenteric artery above the ileocolic artery and runs to the right to the ascending colon behind the peritoneum and crosses in front of the right ureter, right testicular or ovarian vessels and the right psoas major muscle. At or near the ascending colon it divides into ascending and descending branches which anastomose with the middle colic and the iliocolic artery respectively.

Sometimes the iliocolic and the right colic arteries arise by a common trunk or it may arise at a higher level and crosses in front of the second part of the duodenum and the lower pole of the right kidney before it reaches the ascending colon.

(*e*) The **middle colic artery** arises from the right side of the superior mesenteric artery immediately below the neck of the pancreas and running downwards and forwards in between the two layers of the mesentery it divides into right and left branches. The right branch anastomoses with the right colic artery while its left branch passes to the left and ends by anastomosing with the ascending branch of the left colic artery. Together with the left colic artery (ascending branch) it supplies the transverse colon.

C. **The inferior mesenteric artery** supplies the left half of the transverse colon, descending colon, pelvic colon and the greater part of the rectum. It arises from the front of the abdominal aorta about 1½ inches above its bifurcation. It at first lies in front of the abdominal aorta, then descends downwards on its left side, and opposite the pelvic brim, it crosses in front of the left common iliac artery on the right side of the ureter. There it descends downwards into the pelvic cavity in between the two layers of the pelvic mesocolon and becomes the superior rectal artery.

Branches :

(*a*) Superior left colic (*i*) Ascending. (*ii*) Descending.
(*b*) Inferior left colic—Two or three in number.
(*c*) Superior rectal.

Development. The inferior mesenteric artery is the artery of the hind-gut and is derived from the dorsal aorta of which it is a ventral branch.

Anomalies. The inferior mesenteric artery may be absent and replaced by the branches from the superior mesenteric artery. The hepatic, renal or the middle colic arteries may occasionally arise from the inferior mesenteric artery.

(*a*) The **superior left colic artery** passes to the left and crosses in front of the left psoas major, left ureter and left testicular or ovarian vessels and then divides into ascending and descending branches. The ascending branch runs upwards in between the two layers of the transverse mesocolon and anastomoses with the middle colic artery. The descending branch anastomoses with the first branch of the inferior left colic artery.

(*b*) The **inferior left colic artery** consists of two or three arteries and descend downwards in front of the left psoas major, ureter and testicular or ovarian vessels behind the peritoneum and supplies the descending colon, pelvic colon and the upper part of the rectum. Superiorly it anastomoses with the superior left colic

artery and inferiorly it anastomoses with the superior rectal artery but the latter anastomosis is often imperfect.

(c) The **Superior rectal artery** is the main artery supply of the rectum and it begins as a direct continuation of the inferior mesenteric artery and descends downwards between the two layers of the pelvic mesocolon and reaching the level of the third sacral vertebra it divides into two branches which descend one on each side of the rectum. Reaching the middle of the rectum, each artery breaks up into smaller branches which pierce the wall of the gut and descend downwards between the muscular and mucous layers as far as the level of the *sphincter ani internus* where they anastomose each other and form a loop around the lower part of the rectum; these arterial loops communicate with the middle rectal branch of the internal iliac and with the inferior rectal branch of the internal pudendal artery. The superior rectal artery supplies the whole of the mucous membrane and the upper part of the musculature of the rectum. The lower part of the musculature of the rectum is supplied by the middle and inferior rectal arteries.

(2) Branches supplying the three paired glands—These are paired branches which supply the kidneys, suprarenals and the testis or ovary.

(a) The **renal arteries** are two in number, one on each side and supply the right and the left kidneys. The right renal artery is longer than the left because of the aorta being placed more on the left side and in its course it passes behind the inferior vena cava, head of the pancreas and the second portion of the duodenum and finally it reaches the hilum of the right kidney where it is placed in between the renal vein in front and the pelvis of the ureter behind. The left renal artery is shorter than the right and arises from the aorta at a higher level than the right. In its course to the hilum of the left kidney it lies behind the left renal vein and the body of the pancreas and is crossed by the inferior mesenteric vein. Each renal artery provides one inferior suprarenal artery for the corresponding suprarenal gland.

Development. The renal arteries represent the visceral or splanchnic branches from the dorsal aorta

Anomalies. There may be two renal arteries on one or both sides; the two renal arteries, one for each kidney, may arise by a single stem. Accessory renal arteries are also frequently seen. They may be situated either below (usual) or above the normal artery. The accessory renal artery may take its origin from the abdominal aorta, common iliac, external or internal iliac, testicular or ovarian, median sacral arteries or from the lumbar artery; it may also take its origin from the inferior phrenic artery. The kidney develops primarily in the region of the first sacral vertebra and then gradually ascends upwards to gain its normal position; as it ascends it changes its vascular supply but occasionally some of the arteries supplying it earlier may persist to account for the accessory renal arteries.

(b) The **middle suprarenal artery** is a slender artery which arises from each side of the abdominal aorta. The right middle suprarenal artery passes behind the inferior vena cava, and in front of the right crus of the diaphragm. The left middle suprarenal artery comes into relation with the left coeliac ganglion, body of the pancreas and the splenic vessels.

(c) The **testicular arteries** are two in number, one on each side, and supply the testis. Each arises from the front of the aorta immediately below the renal artery and descends obliquely downwards and laterally in front of the psoas major muscle. It crosses the ureter and the genitofemoral nerve, and in the lower part, it descends on the external iliac artery and then enters into the deep inguinal ring where it enters into the spermatic cord. Passing through the spermatic cord it traverses the inguinal canal, the superficial inguinal ring and finally reaches the upper end of the testis where it breaks up into branches, some of which supply the testis and the others anastomose with the artery to the vas deferens.

In the abdomen the right testicular artery passes in front of the inferior vena cava, and behind the third portion of the duodenum, right colic and the ileocolic vessels and the terminal part of the ileum. The left testicular artery passes behind the left colic vessels and the lower part of the descending colon.

terval between the upper border of the interosseous membrane and the oblique cord where it ends by dividing into *anterior* and *posterior interosseous branches*.

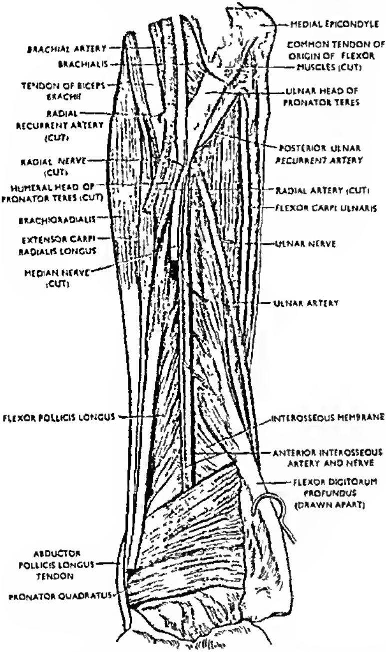


Fig. 620. The deep dissection of the front of the right forearm. The flexor digitorum profundus has been drawn apart and the tendon of the flexor pollicis has been divided.

From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

Anterior interosseous artery. It descends in front of the interosseous membrane in company with the anterior interosseous nerve; reaching the upper border of the pronator quadratus it pierces through the membrane to reach the lower part of the back of the forearm where it joins with the posterior interosseous artery and finally joins in the dorsal carpal anastomosis. In the front of the forearm it is overlapped by the flexor digitorum profundus medially and the flexor pollicis longus laterally. In the back of the hand it lies on the lower part of the back of the intero-

sseous membrane, back of the lower end of the radius in the compartment for the extensor digitorum and extensor indicis tendons. The posterior interosseous nerve comes into close relation with it in the back of the forearm and wrist.

The anterior interosseous artery provides *muscular* and *nutrient* branches, *the arteria mediana* and *an anastomosing branch which joins in the volar carpal network.* The *muscular branches* supply the adjacent muscles. The *nutrient branches* supply the ulna and the radius as their nutrient arteries. The *arteria mediana* arises from the anterior interosseous artery in the upper forearm and soon accompanies the median nerve and ends by supplying its connective tissues. However, it may, occasionally, be sufficiently enlarged and may join with the superficial branch of the ulnar artery to complete the superficial palmar arch.

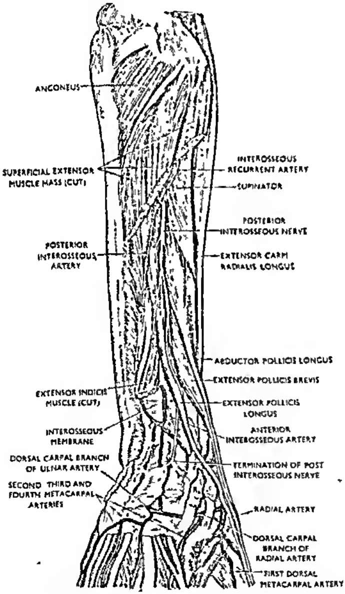


Fig. 621. The deep dissection of the back of the right forearm. Note the posterior interosseous artery and the dorsal carpal anastomosis.
From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

Posterior interosseous artery. It goes to the back of the forearm by passing between the oblique cord and the upper border of the interosseous membrane. In the back of the forearm it runs downwards from below the lower border of the supinator muscle and lies in between the superficial and the deep groups of the extensor muscles of the forearm. In the lower part of the forearm it is accompanied by the posterior interosseous nerve and ends by joining with the anterior interosseous artery and the dorsal carpal network.

Immediately below the lower border of the supinator muscle it provides its *interosseous recurrent branch* which ascends upwards to reach the back of the lateral epicondyle where it ends by joining with the posterior descending branch of the arteria profunda brachii, ulnar collateral and with the posterior ulnar recurrent arteries. It also provides *muscular branches* which supply the adjacent muscles.

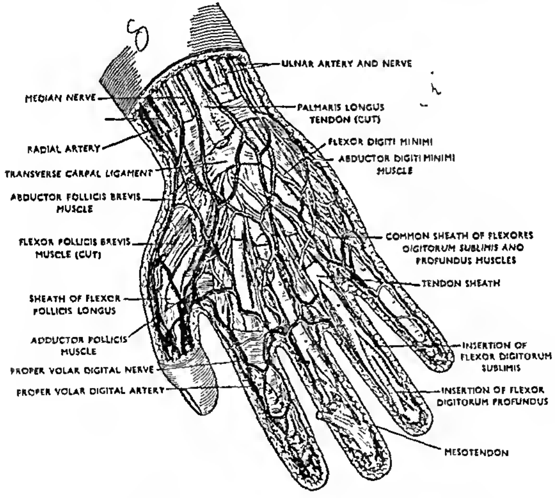


Fig. 622. The palmar aspect of the right palm to show the superficial vessels and nerves. With the kind permission from Lederle Laboratories—drawn by Mr. Paul Peck.

Ulnar artery in the wrist. Posteriorly, in the wrist, the ulnar artery lies upon the flexor retinaculum and is covered *superficially* by the skin, superficial fascia and the palmaris brevis and the fibrous expansion stretching from the flexor carpi ulnaris to the flexor retinaculum. *Medially* it is related to the pisiform hone and the ulnar nerve. *Laterally* it is related to flexor digitorum superficialis (sublimis). Immediately entering into the palm the ulnar artery divides into superficial and deep branches. The former forms the superficial palmar arch while the latter joins with the radial artery to form the deep palmar arch.

Branches in wrist:
(1) Volar (anterior) carpal.
(2) Dorsal (posterior) carpal.

Branches in the hand:
(1) Superficial.
(2) Deep.

Superficial palmar arch. *Formation.* The superficial palmar arch is the direct continuation of the superficial branch of the ulnar artery and forms an arch the convexity of which is directed downwards and lies in between the wrist joint and the root of the middle finger.

The arch is completed on the radial side by the superficial palmar branch of the radial artery which passes in front of or through the thenar muscles and then joins with it. The arch may also be completed by a branch either from the radialis indicis or arteria princeps pollicis from the radial artery or by the arteria mediana.

Relations—Anteriorly. It is covered by the skin, superficial fascia, palmaris brevis, palmar aponeurosis and the palmar branches of the median and ulnar nerves.

Posteriorly It lies successively upon the medial part of the flexor retinaculum, origins of the hypothenar muscles, the flexor tendons and the digital branches of the ulnar and median nerves.

Branches:

(1) *Cutaneous and muscular branches.* Supply the skin and the short muscles in the palm.

(2) *Palmar digital branches.* They are three in number, they accompany the digital nerves and lie superficial to them and descend on the second, third and fourth lumbrical muscles. Each is joined by the corresponding palmar metacarpal artery from the deep palmar arch and divides into digital branches which supply the contiguous sides of the index and middle, middle and ring and the ring and the little fingers. The medial side of the little finger gets a separate branch.

Development. The ulnar branch of the axial artery takes its origin at the elbow and by passing deep to the flexor muscle-mass it descends vertically to enter into the palm of the hand and joins with the capillary network which subsequently develops into the superficial palmar arch.

Anomalies. The ulnar artery may be absent and its place is taken up by either the arteria mediana or by the anterior interosseous artery. It may arise from the brachial or axillary artery in the arm and may descend downwards superficial to the flexor muscle-mass in the forearm, and may lie either superficial or deep to the deep fascia; in case of its higher origin the common interosseous and the ulnar recurrent arteries usually arise from the brachial artery. Distally it may terminate in the deep palmar arch instead of into the superficial palmar arch

The superficial palmar arch may be absent and its area of distribution is supplied by branches from the deep palmar arch. Instead of being completed by the superficial branch of the radial artery, the superficial palmar arch may be completed either by the arteria princeps pollicis, or by the arteria radialis indicis or by the arteria mediana.

Carpal anastomosis. The carpal anastomosis consists of the arterial anastomosis that exists both in front of and behind the carpal articulations.

(1) *Anastomosis in front of the carpal bones.* The volar (anterior) carpal branch of the radial artery anastomoses with the volar (anterior) carpal branch of the ulnar artery and forms a transverse arterial arch which is joined from above by the anterior and the posterior interosseous branches of the common interosseous artery and is joined from below by the recurrent branches from the deep palmar arch. It thus completes a sort of cruciate anastomosis in front of the carpal bones known as the *volar* (anterior) *carpal anastomosis.*

(2) *Anastomosis behind the carpal bones.* The dorsal (posterior) carpal branch of the radial artery anastomoses with the dorsal (posterior) carpal branch of the ulnar artery and this is joined by the anterior interosseous and posterior interosseous branches of the common interosseous artery and thus completes an arterial arch known as the *dorsal* (posterior) *carpal arch.*

From the posterior carpal arch three dorsal matacarpal arteries arise, each of which divides into two digital branches which supply the contiguous sides of the index and middle, the middle and ring and the ring and little fingers.

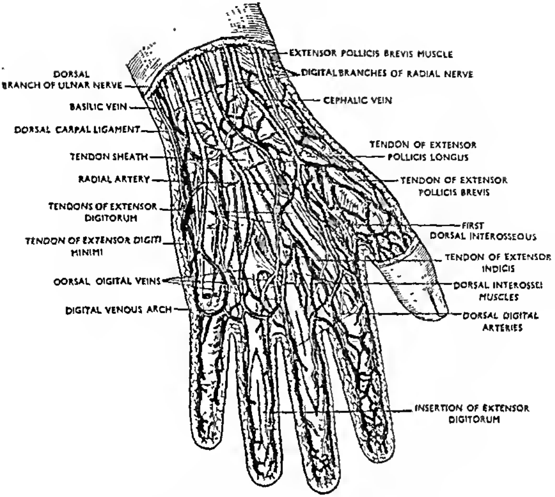


Fig. 623. The dissection of the dorsum of the right hand.
With the kind permission from Lederle Laboratories—drawn by Mr Paul Peck

THE DESCENDING THORACIC AORTA

Descending thoracic aorta. The descending thoracic aorta begins as a direct continuation of the arch of the aorta opposite the level of the lower border of the fourth thoracic vertebra and descending through the posterior mediastinum on the left side of the vertebral column it reaches the front of the twelfth thoracic vertebra where it passes through the aortic opening in the diaphragm and enters the abdomen where it becomes the *abdominal aorta.*

Relations. Anteriorly, from above downwards, it is related to the root of the left lung, pericardium separating it from the left atrium of the heart, oesophagus and the diaphragm. *Posteriorly,* it is related to the vertebral column and intervening between it and the vertebral column are the hemiazygos veins. *To the left* are the left lung and the pleura. *To the right* it is related to the oesophagus with the oesophageal plexus of nerves to the greater part of its extent, and to the azygos vein and the thoracic duct. In the lower part of the posterior mediastinum as it approaches to the front of the vertebral column it is crossed in front by the oesophagus.

Branches:

(1) Pericardial.
(2) Bronchial.
(3) Oesophageal.
(4) Mediastinal.
(5) Posterior intercostal arteries.
(6) Phrenic branches.

(1) *Pericardial.* They are a few small twigs which supply the posterior aspect of the pericardium.

(2) The *bronchial artery* may arise from the descending thoracic aorta or from any of the upper posterior intercostal arteries. There is usually one bronchial artery on the right side whereas on the left side there are two, superior and inferior bronchial arteries. The *right bronchial artery* arises from the third posterior intercostal artery. The *left bronchial arteries* arise from the descending thoracic aorta. The origin of the left superior bronchial artery corresponds to the body

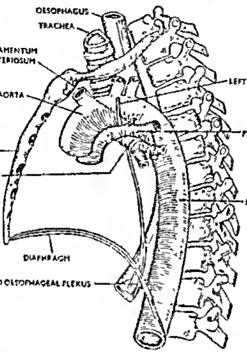


Fig. 624. The descending thoracic aorta in relation to the vertebral column. Seen from the left side.

of the fifth thoracic vertebra whereas the left inferior bronchial artery arises from below the left superior bronchial artery. It enters the substance of the lung behind the bronchii and breaks up into branches which supply the bronchial tubes and the interlobular spaces. *Those supplying the bronchial tubes* break up into minute branches which form two plexuses—one in the sub-muscular coat and the other in the sub-mucous coat. These plexuses communicate with the pulmonary artery and finally open into the pulmonary veins. *Those supplying the interlobular spaces* give origin to the superficial and the deep bronchial veins. The bronchial veins from the right side end in the azygos vein while the bronchial veins from the left lung open into the left superior intercostal vein or into the superior hemiazygos vein.

N.B. From the above facts it is evident that the pulmonary veins do not carry absolutely pure blood because they are to receive some impure blood from the bronchial trees.

Development. The bronchial arteries represent the visceral or the splanchnic branches of the dorsal aorta which fuse together to form the descending thoracic aorta. The origin of the right bronchial artery from the third right posterior intercostal artery, which is a somatic intersegmental artery, is due to the persistence of an anastomosis between the splanchnic artery and the somatic intersegmental artery, the origin of the splanchnic artery from the dorsal aorta being obliterated.

Anomalies. The anomalies found in respect of the bronchial arteries are mostly confined to their different sources of origin. The right bronchial artery may arise from the left superior bronchial artery. This is due to fusion of the two splanchnic branches of the dorsal aortae. It may also arise from the inferior thyroid artery due to the same reason.

The bronchial artery may sometime take its origin either from the internal thoracic (mammary) artery, or from the right or the left subclavian artery. This can be explained in the same way as explained about the origin of the right bronchial artery from the right third posterior intercostal artery.

(3) *Oesophageal.* The oesophageal branches consist of 5 or 6 small arteries which arise from the ventral aspect of the aorta and soon pass to the oesophagus. Superiorly they anastomose with the oesophageal branches of the inferior thyroid artery and inferiorly with the oesophageal branches of the left gastric and the left phrenic arteries.

(4) *Mediastinal.* Several small twigs supply the lymph glands and the areolar tissues of the posterior mediastinum.

(5) *Posterior intercostal arteries.* Each typical posterior intercostal artery arises from the descending thoracic aorta, traverses the costal groove and ends by anastomosing with the anterior intercostal branch of the internal thoracic (mammary) or musculophrenic artery. Aortic intercostal arteries, in series, arise from either sides of the descending thoracic aorta and passing either to the left or right thoracic wall. The posterior intercostal arteries from the third to the ninth intercostal space on both sides maintain the same characteristics and any one of the intercostal arteries of this series may called a *typical aortic intercostal artery.*

The *right aortic intercostal arteries* are larger than the left owing to the aorta being placed on the left side of the vertebral column. They cross the front of the vertebral column and pass behind the oesophagus, thoracic duct and the azygos vein and reach their numerically equivalent space. They all are covered by the right lung and pleura. The *left intercostal arteries* are crossed vertically by the hemiazygos veins and are covered by the left lung and pleura. The further course and relations of the arteries are the same on both the sides.

Each artery reaches the upper border of the numerically equivalent space and passes towards the angle of the upper rib. It then lies in the costal groove and is continued forwards as far as the mid-axillary line where it breaks up into two branches. One follows the lower border of the space and the other the upper broder and ends by anastomosing with the corresponding anterior intercostal branch of the internal thoracic (mammary) or musculophrenic artery.

As far as the angle of the rib the artery lies in between the costal pleura and the internal (posterior) intercostal membrane. In the costal groove it lies between the intercostalis internus and intercostalis intimi muscles. Here it is accompanied by the intercostal vein and the intercostal nerve of which the nerve lies below and the vein lies above the artery.

Branches:

(*a*) Dorsal.
(*b*) Collateral intercostal
(*c*) Muscular.
(*d*) Lateral cutaneous.
(*e*) Mammary.

N.B. Of the typical series the third aortic intercostal artery is an exception which ends by anastomosing with the superior intercostal artery. The intercostal arteries of the lower two spaces, that is, the 10th and the 11th spaces, maintain almost all the characteristics of the typical series so long as they are contained in the costal groove and beyond that they are continued in the anterior abdominal wall where they lie in between the obliquus internus abdominis and the transversus abdominis and end by anastomosing with the subcostal, superior epigastric and lumbar arteries.

Dorsal branch. The dorsal branch of the intercostal artery runs backwards between the necks of two ribs and medial to the superior costo-transverse ligament and then accompanies the posterior primary ramus of the thoracic spinal nerve and finally after crossing over the transverse process of the thoracic vertebra it divides into terminal branches which supply the adjacent muscles and the skin. The cutaneous twigs accompany the cutaneous twigs of the posterior primary ramus of the thoracic spinal nerve.

As the dorsal branch passes backwards it gives out its *spinal branch* which enters into the vertebral canal through the intervertebral foramen and divides into branches which supply the vertebrae, the spinal meninges and the medulla spinalis (spinal cord). Over the medulla spinalis it anastomoses with the artery of the opposite side and with the spinal arteries.

Collateral intercostal branch. This branch arises from the posterior intercostal artery opposite the angle of the rib. It runs downwards and laterally to reach the upper border of the rib below and follows the same to the anterior chest wall where it ends by anastomosing with the intercostal branch of the internal thoracic (internal mammary) and musculo-phrenic arteries.

Muscular branches. They supply the intercostal muscles, pectoralis major, pectoralis minor and the serratus anterior muscles.

Lateral cutaneous branches. These branches follow the corresponding lateral cutaneous nerve from the ventral ramus of the thoracic spinal nerve and are mostly distributed to the skin.

Mammary branches. The posterior intercostal arteries of the second, third and the fourth intercostal spaces provide mammary branches which supply the breast.

N.B. The right bronchial artery arises from the right posterior intercostal artery.

Development. The posterior intercostal arteries represent the somatic intersegmental branches from the dorsal aorta.

Anomalies. The posterior intercostal arteries are bilateral vessels from the descending thoracic aorta, each arising separately. Each pair may, however, arise by a common stem or one intercostal artery may supply more than one intercostal spaces. The origin by a common stem is due to fusion of the roots of two somatic intersegmental arteries. In cases, where one intercostal artery supplies more than one intercostal spaces, the precostal anastomosis of the particular somatic intersegmental arteries persists whereas the connection of the intersegmental arteries with the dorsal aorta internal to the precostal anastomosing channel retrogresses except the one which becomes the feeder stem.

The number of the posterior intercostal arteries may also either increase or decrease.

(*b*) *Phrenic branches.* They form a few small twigs arising from the lower part of the descending thoracic aorta and supply the diaphragm and end by anastomosing with the musculophrenic and pericardiacophrenic arteries.

THE ABDOMINAL AORTA

The abdominal aorta. It lies in front of the vertebral column and begins as a direct continuation of the thoracic aorta from opposite the level of the twelfth thoracic vertebra and ends below, opposite the body of the fourth lumbar vertebra, by dividing into right and left common iliac arteries. At its termination it is placed a little to the left of the median plane.

Anteriorly, from above downwards, it is related to the coeliac artery with coeliac plexus of nerves, peritoneum of the lesser sac, superior mesenteric artery, body of the pancreas, left renal vein, the third part of the duodenum and the parietal peritoneum which separates it from some coils of the small intestine.

Posteriorly, it is related to the bodies of the upper four lumbar vertebrae, anterior longitudinal ligament, the lumbar arteries and the left lumbar veins.

To the left side, from above downwards, are the left crus of the diaphragm, the body of the pancreas, duodeno-jejunal flexure, fourth part of the duodenum, some coils of the small intestine and the left sympathetic trunk.

To the right side, are the inferior vena cava and the right sympathetic trunk to the greater part of its extent, and higher up, where the inferior vena cava deviates to the right it is related to the right crus of the diaphragm and the origin of the azygos vein and the cisterna chyli.

The branches of the abdominal aorta may be grouped into the (1) branches supplying the gastro-intestinal tract and the three unpaired glands (liver, spleen and the pancreas), (2) the branches supplying the three paired glands (testis or ovary, kidney and the suprarenal gland) and (3) the branches supplying the body walls.

(1) The branches supplying the gastro-intestinal tract and the three unpaired glands are the unpaired ventral branches of the aorta and from above downwards they are the (*a*) Coeliac, (*b*) the superior mesenteric and (*c*) the inferior

mesenteric. They are unpaired because they are formed by the fusion of the ventral branches of the two dorsal aorta in prenatal life.

A. The coeliac artery. It is the first anterior branch of the abdominal aorta and arises from it immediately below the aortic opening in the diaphragm. It is a stout branch, about half an inch in length and passes horizontally forwards above the pancreas and the splenic vein. Soon after its origin it divides into its terminal branches.

It is surrounded by the coeliac plexus of nerves, the branches of which accompany the branches of the coeliac artery. *On the right side*, it is related to the right crus of the diaphragm, the right coeliac ganglion and the caudate lobe of the liver. *On its left side*, are the left coeliac ganglion, the left crus of the diaphragm and the left gastric artery. *Below* it is related to the pancreas and the splenic vein.

N.B. The coelic artery in prenatal life was situated in the neck opposite to the seventh cervical vertebra but later on, when the lungs develop they push the diaphragm downwards and the diaphragm in turn pushes down the coeliac artery. The median arcuate ligament which connects the two crura of the diaphragm opposite the median plane, forms a tight collar above the coeliac artery.

Branches:

(*i*) Left gastric,
(*ii*) Hepatic
(*iii*) Splenic.

Development. The coeliac artery represents the artery of the fore-gut and forms the ventral branch from the abdominal portion of the dorsal aorta.

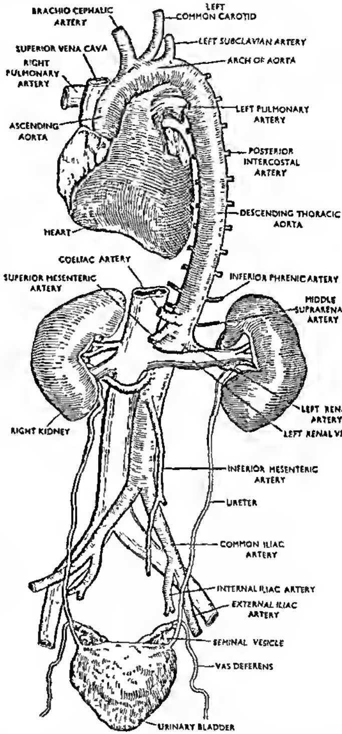


Fig. 625. The heart with the aorta with its parietal and visceral branches. From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

Anomalies. The *coeliac artery* may be absent; when absent, its branches may take origin separately from the abdominal aorta or from some other arteries.

The *hepatic artery* may arise either from the abdominal aorta or from the superior mesenteric artery; the left hepatic artery occasionally arises from the left gastric artery.

The *left gastric artery* may be double and may take origin separately from the abdominal aorta.

The *splenic artery* may arise either from the abdominal aorta or from the superior or inferior mesenteric arteries, it may also take its origin from either the middle colic or from the left hepatic artery.

(i) The **left gastric artery** passes upwards and to the left towards the oesophageal opening in the diaphragm and after giving its oesophageal branch which passes through the oesophageal opening, descends downwards and to the right along the lesser curvature of the stomach and ends by anastomosing with the right gastric artery opposite the pyloric end of the stomach. It lies between the two layers of the lesser omentum. It gives branches which are distributed to the two walls of the stomach.

(ii) The **splenic artery** passes transversely to the left side and is remarkable for its tortuosity. In its course it grooves in the posterior surface of the body of the pancreas above the splenic vein and crosses the left psoas major muscle, left suprarenal gland and the anterior surface of the left kidney and finally it enters between the two layers of the lienorenal ligament and divides into branches which enter into the hilum of the spleen above the splenic vein.

Branches:

(*a*) Pancreatic.
(*b*) Short gastric.
(*c*) Left gastroepiploic.
(*d*) The terminal or splenic.

(*a*) The **pancreatic branches** of the splenic artery are numerous short branches which supply the body and tail of the pancreas. One of the pancreatic branches, known as the *arteria pancreatica magna*, is a long slender branch which closely accompanies the pancreatic duct and ends by anastomosing with the pancreatic branches from the superior and inferior pancreatico-duodenal arteries.

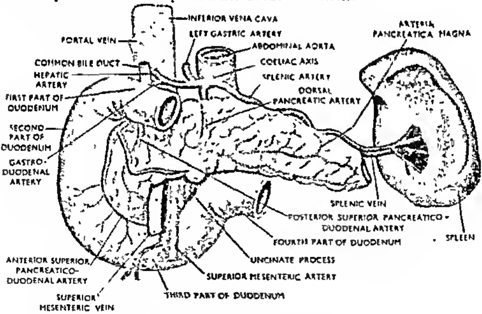


Fig. 626 The duodenum with the pancreas and the spleen.
Note the closely related vessels in association with these viscera.

(*b*) The **short gastric** arteries are five or six short branches which arise from the left end of the splenic artery and also from its terminal branches and by passing between the two layers of the gastrosplenic omentum they supply the fundus of the stomach and end by anastomosing with the branches from the left gastric and the left gastroepiploic arteries.

(*c*) The **left gastroepiploic artery** arises from the splenic artery close to its left end. It is the largest branch of the splenic artery and insinuating itself between the two layers of the gastrosplenic omentum it passes to the right in between the two layers of the greater omentum along the greater curvature of the stomach and anastomoses with the right gastroepiploic artery. In its course through the greater omentum it lies at a distance of about half an inch from the greater curvature of the stomach and provides ascending and descending branches. The ascending branches supply the stomach while the descending branches supply the greater omentum.

(*d*) The **splenic branches** form the terminal branches of the splenic artery which enter the hilum of the spleen between the two layers of the lienorenal ligament and end by supplying the spleen.

(*iii*) The **hepatic artery** passes forwards and to the right from its origin to the upper border of the first part of the duodenum and then it passes upwards to enter into the right margin of the lesser omentum where it is placed on the left side of the common bile duct and in front of the portal vein. Finally it reaches the right end of the porta hepatis where it ends by dividing into right and left branches for the corresponding lobe of the liver. It is accompanied by the hepatic plexus of nerves.

Branches:

(*a*) Right gastric.
(*b*) Gastroduodenal.
  (*i*) Right gastroepiploic.
  (*ii*) Superior pancreatico-duodenal.
(*c*) Cystic.

(*a*) The **right gastric artery** arises from the hepatic artery immediately above the first portion of the duodenum and then descends downwards in between the two layers of the lesser omentum to reach the pylorus. It then passes to the left along the lesser curvature of the stomach and after supplying branches to both surfaces of the stomach it ends by anastomosing with the left gastric artery.

(*b*) The **gastroduodenal branch** of the hepatic artery arises from the hepatic artery above the medial part of the first portion of the duodenum and then descends behind it and lies on the left side of the common bile duct and reaching the lower border of the same it divides into right gastroepiploic and superior pancreatico-duodenal branches.

(*i*) The *right gastroepiploic artery* after its origin soon passes to the left to the greater curvature of the stomach where it lies in between the two layers of the greater omentum and passing along the greater curvature it ends by anastomosing with the left gastroepiploic branch of the splenic artery. At the lower border of the pylorus it lies in contact with the same but in the rest of its extent it lies at a distance of about half an inch from the greater curvature of the stomach.

(*ii*) The *superior pancreatico-duodenal artery* forms two arterial arches, anterior and posterior. The anterior one passes in front of the groove between the head of the pancreas and the second part of the duodenum and ends by anastomosing with the pancreatic branches from the splenic artery and with the anterior branch of the inferior pancreatico-duodenal branch of the superior mesenteric artery. The posterior branch passes downwards and to the right from under cover of the first part of the duodenum and then passes in front of the portal vein and the common bile duct. Then it passes behind the head of the pancreas and crosses in front of the bile duct to reach the medial wall of the duodenum (second part) and finally descends in the posterior part of the groove between it and the head of the pancreas and ends by anastomosing with the posterior branch of the inferior pancreatico-duodenal artery.

(c) The *cystic artery* arises from the right branch of the hepatic artery within the porta hepatis and passing behind the common hepatic duct reaches the back of the cystic duct and the neck of the gall bladder where it intervenes between the liver and the neck of the gall bladder and divides into superficial and deep branches. The superficial branch passes between the peritoneum and the gall bladder while the deep branch runs between it and the liver and they finally end by supplying the gall bladder.

B. **The superior mesenteric artery** arises from the front of the abdominal aorta about 1 cm below the origin of the coeliac artery and descends downwards and to the right between the two layers of the mesentery to the right iliac fossa where it ends by anastomosing with one of its own branches—the iliocolic branch.

At its origin it is crossed by the neck of the pancreas and the splenic vein and it is separated from the front of the abdominal aorta by the left renal vein. In its course downwards and to the right it crosses in front of the uncinate process of the pancreas, the third portion of the duodenum, the right testicular or ovarian vessels, the inferior vena cava, the right psoas major muscle and the right ureter. It is accompanied by the superior mesenteric vein which lies on its right side. The mesenteric plexus of nerves intimately surrounds the artery.

The superior mesenteric artery supplies the whole of the small intestine except the first portion of the duodenum, it also supplies the caecum, ascending and the transverse colon (Rt. 2 3).

Development. The superior mesenteric artery is the artery of the mid-gut and is derived from the dorsal aorta of which it is a ventral branch

Anomalies. Occasionally it supplies both the mid- and the hind-guts; in such cases the inferior mesenteric artery is usually absent There may be two superior mesenteric arteries occasionally The gastroduodenal, splenic and the hepatic arteries may occasionally arise from the superior mesenteric artery

Branches:

(a) **The inferior pancreatico-duodenal artery** arises from the superior mesenteric artery immediately above the upper border of the third part of the duodenum. Sometimes it may arise from the first jejunal branch of the superior mesenteric artery. After its origin it soon divides into anterior and posterior branches. The anterior branch passes upwards and to the right to reach the anterior aspect of the groove between the head of the pancreas and the second portion of the duodenum and ends by anastomosing with the anterior branch of the superior pancreatico-duodenal artery. The posterior branch reaches the posterior aspect of the groove between the head of the pancreas and the second portion of the duodenum and anastomoses with the posterior branch of the superior pancreatico-duodenal artery.

(b) **Jejunal and ileal branches** of the superior mesenteric artery arise from the left side of the same and consist of about 12 to 15 branches. Except the terminal portion of the ileum which is supplied by the ileocolic artery, the whole of the jejunum and the ileum are supplied by these branches. Each artery first divides into two branches which unite with the similar adjacent branches to form arterial arches and ultimately before reaching the intestine they form numerous arches in between the two layers of the mesentery. From each of the terminal arches a single straight artery (vasa recti) reaches the gut wall and these straight arteries alternately pass to the left and right side of the gut wall and end by supplying them. The vasa recti supplying the jejunum are longer than those supplying the ileum.

(c) **The ileocolic artery** arises from the right side of the superior mesenteric artery below the right colic artery and forms the lowest of the branches on the right side. It runs downwards and to the right to reach the right iliac fossa where it divides into superior and inferior branches. The superior branch anastomoses with the right colic artery while the inferior branch anastomoses with the terminal portion of the superior mesenteric artery. In its course the ileocolic artery lies behind the

The **ovarian artery** in the female corresponds to the testicular artery in the male and has the same course and relation up to the pelvic brim. It enters the pelvic cavity by crossing the external iliac vessels and then runs medially in between the two layers of the infundibulopelvic ligament and reaches the hilum of the ovary where it gives out branches which supply the ovary and finally ends by anastomosing with the uterine artery.

Development. The testicular or ovarian arteries represent the splanchnic branches from the dorsal aorta which supply the gonads from which either the testis or the ovary develops. The origin of the arteries from the upper lumbar region is indicated by the fact that the gonads occupy the same region during the earlier part of the development but subsequently, due to descent of the testis or the ovary, the artery supplying the organ is dragged down with it and becomes elongated.

Anomalies. The testicular or the ovarian arteries may arise by a common stem; they may be double on one or both sides. The artery may take its origin either from the suprarenal, renal or from the accessory renal arteries instead of from the abdominal aorta.

(3) *Branches supplying the body walls*—The arteries supplying the body wall are the two inferior phrenic arteries, four pairs of lumbar arteries and the median sacral artery.

The **inferior phrenic arteries** are two in number, each arising from the front of the abdominal aorta above the coeliac artery. The size and origin of the arteries are constantly variable and after a short course each artery enters into the diaphragm muscle and ends by supplying it. In the diaphragm they anastomose each other and also with the branches from the posterior intercostal and musculophrenic arteries. Each inferior phrenic artery provides a superior suprarenal branch which supplies the suprarenal gland.

The **lumbar arteries** are four in number on each side and they arise from the posterior aspect of the abdominal aorta. Each artery passes backwards round the body of the lumbar vertebra and passes laterally behind the quadratus lumbroum except the last one which usually passes in front of the muscle, and enters into the abdominal wall where it lies between the transversus and the obliquus internus abdominis and ends by anastomosing with the posterior intercostal arteries. In their course the upper arteries pass behind the crus of the diaphragm, psoas major muscle and the sympathetic trunk while the lower arteries pass behind the psoas major and the sympathetic trunk only.

The **median sacral artery** arises from the back of the abdominal aorta immediately above its bifurcation and then runs downward in front of the left common iliac vein and the sacral promontory and then it enters the pelvic cavity and descends vertically downwards in front of the sacrum opposite to the median plane and ends by anastomosing with the lateral sacral arteries.

Right common iliac artery. It is about 2 inches long and passes obliquely downwards and laterally upto its division into external and internal iliac arteries. *Anteriorly* it is covered by the parietal peritoneum which separates it from some coils of the small intestine. Under the parietal peritoneum it is crossed in front by the sympathetic nerves passing to the hypogastric plexus, and near its termination, by the ureter. *Posteriorly* it lies against the bodies of the fourth and the fifth lumbar vertebrae and is separated from them by the commencement of the inferior vena cava, termination of the common iliac veins and the sympathetic trunk. Opposite the lumbosacral triangle it is related deeply to the obturator nerve, the lumbosacral nerve trunk and the iliolumbar artery. *Laterally* it is related to the inferior vena cava above and to the right common iliac vein below. *Medially* it is related to the left common iliac vein in its upper part.

Left common iliac artery. The left common iliac artery is shorter than the right and measures about 1½ inches in length. It is covered in front by the parietal peritoneum which separates it from some coils of the small intestine. Under the parietal peritoneum it is crossed by the sympathetic branches which pass to the

hypogastric plexus and near its termination by the ureter and in between the two by the inferior mesenteric or superior rectal vessels. Posteriorly it is related to the obturator nerve, lumbosacral trunk and the iliolumbar artery and a part of the left common iliac vein. Laterally it is related to the left psoas major muscle and medially to the left common iliac vein.

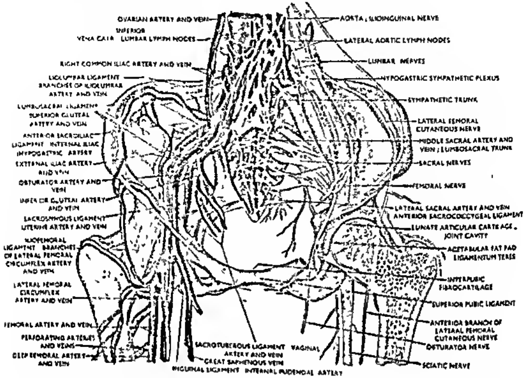


Fig 627. Anatomy of the pelvis and hip joint. Note the disposition of the external and internal iliac arteries.

With the kind permission from Lederle Laboratories—drawn by Mr. Paul Peck.

External iliac artery. The external iliac arteries are two in number, one on each side, and begins at the bifurcation of the common iliac artery. Descending obliquely downwards and laterally it passes behind the mid-point of the inguinal ligament and enters the thigh behind it to become the femoral artery.

Anteriorly it is covered by the parietal peritoneum which separates the left artery from the pelvic colon and some coils of the small intestine and the right artery from the terminal part of the ileum, and sometimes from the vermiform appendix. At its commencement it is crossed by the ureter and near its termination by the deep circumflex iliac vein, genital branch of the genitofemoral nerve, and by the vas deferens in the male, and the round ligament of the uterus in the female. The testicular vessels in the male descend in front of it whereas the ovarian vessels in the female cross in front of it. Posteriorly and laterally it is related to the psoas major muscle being separated by the fascia iliaca. The external iliac vein lies medial to it at its lower part but posterior to it in its upper part.

Branches. It gives out the inferior epigastric and the deep circumflex iliac artery and a few muscular twigs.

Inferior Epigastric Artery. The inferior epigastric artery arises from the external iliac artery immediately above the inguinal ligament and ascends upwards and medially in the extra-peritoneal tissue close to the medial margin of the deep inguinal ring and then it passes upwards between the posterior lemella of the rectus sheath

and the rectus abdominis muscle. Finally it breaks up into branches which end by anastomosing with the superior epigastric branch of the internal mammary artery and the posterior intercostal arteries.

At first it lies in the extra-peritoneal tissue in front of the peritoneum, then on the transversalis fascia, and is covered by the transversus abdominis muscle, and in the rectus sheath, by the rectus abdominis muscle. It lies below and medial to the deep inguinal ring, and the vas deferens, in case of male, and the round ligament of the uterus in case of female, winds round the posterior and lateral aspects of the artery.

Branches:

(1) Pubic.
(2) Cremasteric.
(3) Peritoneal.
(4) Muscular branch.
(5) Cutaneous branch.
(6) Terminal.

Pubic branch. It arises from the inferior epigastric artery close to its origin and descends downwards along the medial margin of the femoral ring (free margin of the pectineal part of the inguinal ligament) to reach the back of the body of the pubis where it ends by anastomosing with the pubic branch of the obturator artery. Sometimes the pubic branch of the inferior epigastric artery becomes sufficiently enlarged to replace the obturator artery which is absent. In such cases this branch is known as the *abnormal obturator artery*.

Cremasteric branch. It is a small artery from the inferior epigastric artery which descends through the inguinal canal and supplies the cremaster muscle and the other coverings of the spermatic cord and ends by anastomosing with the external pudendal, scrotal or labial artery and with the testicular artery in the male. It is much smaller in the female and accompanies the round ligament of the uterus.

Peritoneal branches. They are small branches which supply the lower part of the peritoneum and the extraperitoneal connective tissue.

Muscular branches. They supply the muscles of the anterior abdominal wall and end by anastomosing with the deep circumflex iliac, lower posterior intercostal and lumbar arteries.

Cutaneous branches. They pierce the rectus abdominis and its anterior sheath and are distributed to the subcutaneous tissue of the anterior abdominal wall where they anastomose with the superficial epigastric and the corresponding branches of the opposite side.

Terminal branches. They end by anastomosing with the branches of the superior epigastric artery within the musculature of the rectus abdominis muscle.

Deep circumflex iliac artery. It arises from the lateral aspect of the external iliac artery immediately above the inguinal ligament and being contained in a sheath derived from the transversalis fascia (in front) and the fascia iliaca (behind) it passes upwards and laterally behind the inguinal ligament to reach the anterior superior iliac spine. Here it pierces the transversalis fascia and runs along the inner lip of the iliac crest upto its mid-point where it pierces the transversus abdominis and runs backwards along the inner lip of the iliac crest between the transversus abdominis and the obliquus internus abdominis and finally ends by anastomosing with the superior gluteal and iliolumbar arteries. Opposite the anterior superior iliac spine it anastomoses with the ascending branch of the lateral circumflex femoral artery and provides an ascending branch which intervenes between the transversus abdominis and the obliquus internus abdominis and ends by anastomosing with the lumbar arteries and with the branches from the inferior epigastric arteries.

~~The internal iliac artery~~. It is about 1½ inches long and begins from opposite the level of the sacroiliac joint as the internal terminal branch of the common iliac artery. It descends downwards to the upper part of the greater sciatic where it divides into anterior and posterior trunks.

Anteriorly it is related to the ureter in the male and with the ureter, ovary and the fimbriated end of the uterine tube in the female. *Posteriorly* it is related to the internal iliac vein, lumbosacral nerve trunk and the sacro-iliac articulation. Medially it is related to the parietal peritoneum which separates it from some coils of the ileum and the pelvic colon above, and from the ureter below. Laterally it is related to the external iliac vein above and to the obturator nerve below.

Branches:

Anterior trunk: umbilicus.

(*a*) Superior vesical.
(*b*) Inferior vesical.
(*c*) Middle rectal:
(*d*) Uterine and vaginal (in case of female only).
(*e*) Obturator.
(*f*) Internal pudendal.
(*g*) Inferior gluteal.

Posterior Trunk:

(*a*) Iliolumbar.
(*b*) Lateral sacral.
(*c*) Superior gluteal.

The superior vesical artery. The superior vesical artery arises as three or four small arteries from the patent portion of the obliterated umbilical artery. They supply the superolateral aspects of the urinary bladder. They also supply the terminal portion of the ureter and the vas deferens.

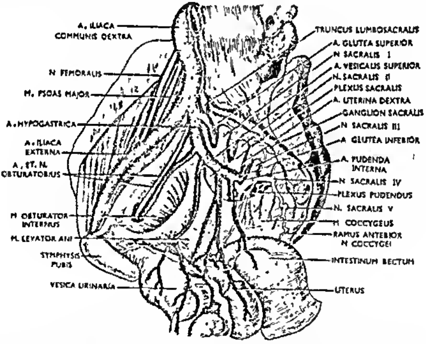


Fig. 620. Lateral view of the female pelvis to show the main arteries and nerves. The bladder, rectum and pelvic genitation are drawn downwards to show their arterial supply. With the kind permission from: Callanders Surgical Anatomy 2nd edition 1939, W. B. Saunder's company: Philadelphia and London.

The inferior vesical artery. It usually arises by a common trunk with the middle rectal artery and supplies the inferolateral aspects of the urinary bladder, terminal portion of the ureter and sometimes the vas deferens.

The middle rectal artery. It usually arises in common with the inferior vesical artery but it may spring from the anterior trunk immediately below the patent por-

tion of the obliterated umbilical artery. It supplies the rectum and ends by anastomosing with the *inferior* and *superior rectal arteries*. It also supplies the urinary bladder, prostate and the *seminal vesicles*.

The vaginal artery. The vaginal artery of the female replaces the inferior vesical artery of the male and supplies the vagina, vestibule, the bladder and the adjoining portions of the rectum. It helps in the formation of the azygos artery of the vagina (see below).

Uterine artery. It arises from the anterior trunk of the internal iliac artery and runs medially in the levator ani muscle in parallel to the lateral side of the ureter. It then ascends over the lateral fornix of the vagina to reach the side of the cervix uteri where it lies at a distance of 2 cm. from the cervix and crosses in front of the ureter and then ascends upwards in between the two layers of the broad ligament. Coursing along the side of the uterus it reaches the junction of the uterus with the uterine tube and then runs laterally below the uterine tube towards the hilum of the ovary and ends by anastomosing with the ovarian artery. It supplies branches to the uterus, uterine tube, round ligament of the uterus and the vagina.

The vaginal branches of the uterine artery anastomose with the vaginal arteries and form two median longitudinal arteries known as the *azygos arteries of the vagina*. One of them passes in front of the vagina while the other passes behind it.

Obturator artery. It arises from the ventral division of the internal iliac artery and runs downwards and forwards on the lateral wall of the pelvis to reach the obturator foramen where it is placed above the obturator vein and below the obturator nerve. Then it passes through the obturator canal and finally divides into anterior and posterior branches. In the pelvis it is related medially to the ureter and the vas deferens. In the female it lies in the floor of the ovarian fossa and is separated from its lateral surface by the parietal peritoneum.

Branches:

(1) Iliac.
(2) Vesical.
(3) Pubic.
(4) Anterior.
(5) Posterior.

Iliac branches. They pass to the iliac fossa where they supply the iliacus muscle and provide a *nutrient* branch which supplies the ileum and finally its branches anastomose with the branches of the iliolumbar artery.

Vesical branch. The vesical branch or branches run medially to supply the urinary bladder.

Pubic branch. It arises from the obturator artery immediately before it leaves the pelvic cavity. It runs upwards on the pelvic surface of the pubis and ends by anastomosing with the fellow of its opposite and with the pubic branch of the inferior epigastric artery.

Anterior branch. It is one of the terminal branches and is given out from the obturator artery outside the pelvic cavity (all other branches arise from it within the pelvic cavity) and runs forwards and then follows round the margin of the obturator foramen and finally ends by anastomosing with the posterior branch and with the medial circumflex femoral artery. It supplies the adjacent muscles.

Posterior branch. It runs backwards around the margin of the obturator foramen and ends by anastomosing with the anterior branch and with the medial circumflex femoral artery. It provides an *acetabular branch* to the hip joint which enters the acetabulum through the acetabular notch below the transverse acetabular ligament and supplies the head of the femur and its ligament.

Abnormal obturator artery. An abnormal obturator artery (normally the obturator artery arises from the anterior trunk of the internal iliac artery) arises from the inferior epigastric artery and descends either vertically downwards to the

upper part of the obturator foramen or it curves round the medial margin of the femoral ring before reaching the obturator foramen.

When it descends vertically downwards to the obturator foramen it lies in contact with the external iliac vein and is situated on the lateral side of the femoral ring and the artery has the least chance to be involved in the operation of femoral hernia.

When it lies on the free margin of the pectineal part of the inguinal ligament there is every possibility of its being involved in the operation because it almost completely surrounds the neck of the hernial sac.

The obturator artery may also arise from the posterior trunk of the internal iliac, from external iliac or from the superior gluteal artery.

Internal pudendal artery. *course.* The internal pudendal artery arises from the anterior trunk of the internal iliac artery and emerges from the pelvic cavity between the piriformis and the coccygeus and enters into the gluteal region through the lower part of the greater sciatic foramen below the piriformis muscle and then

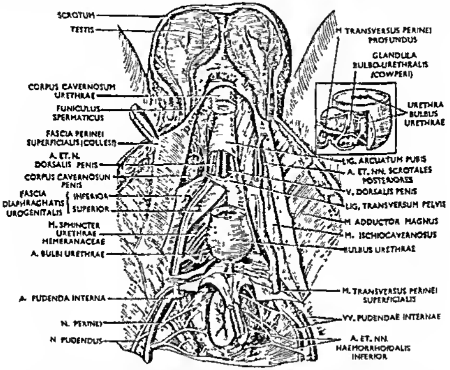


Fig. 629. The deep structures of the perineum.
On the left side, the superficial perineal fascia (of Colles) has been incised and retracted to show the contents of the superficial perineal compartment. On the right side the structures of the deep perineal compartment are exposed through an incision in the inferior fascia of the diaphragm. Note the position of the internal pudendal artery.

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crossing the back of the ischial spine it passes to the lateral wall of the ischiorectal fossa through the lesser sciatic foramen. It then enters the perineum and courses along the ischiopubic rami to reach the subpubic angle where at a distance of about half an inch from the inferior pubic ligament it ends by dividing into deep and dorsal arteries to the penis or clitoris.

Relations. In the pelvis it lies in front of the piriformis muscle, sacral plexus of nerves and the inferior gluteal artery. In the *gluteal region* the pudendal nerve lies medial to it and the nerve to the obturator internus lies on its lateral side and it is

covered by the gluteus maximus muscle. In the *inchiorectal fossa* it lies in the pudendal canal and the dorsal nerve of the penis or clitoris lies above it and the perineal nerve lies below it. In this situation it lies at a distance about $1\frac{1}{2}$ inches from the ischial tuberosity.

Branches:

(1) *Muscular.* Muscular branches arise both in the pelvis and in the gluteal region and supply the muscles in the pelvic cavity and in the gluteal region.

(2) *Inferior rectal.* It arises from the internal pudendal artery as it lies in the pudendal canal and crossing the ischiorectal fossa transversely it reaches the anal region and after supplying the anal canal it anastomoses with the superior and middle rectal arteries.

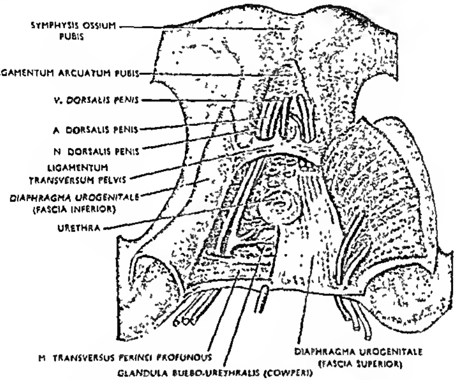

Fig. 630. Contents of the deep perineal compartment.
Note the position of the internal pudendal artery.

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(3) *Scrotal or labial.* It arises from the internal pudendal artery in front of the inferior rectal artery and passes forwards either superficial or deep to the transversus perinei superficialis and then traverses the interspace between the bulbospongiosus and the ischiocavernosus, supplies these muscles and ends in the skin of the scrotum.

(4) *Transverse perineal.* It arises from the internal pudendal artery as it passes deep to the perineal membrane and passes transversely over the transversus perinei superficialis and anastomoses with the fellow of its opposite side.

(5) *Urethral.* It pierces the perineal membrane and enters the corpus spongiosum penis.

(6) *Deep artery of the penis or clitoris.* It is one of the terminal branch of the internal pudendal artery and arises in the deep pouch of the perineum. After piercing the perineal membrane it pierces the crus penis and supplies the erectile tissue.

anastomosing with the median sacral artery. Some of its branches pass through the lower anterior sacral foramina and are distributed in the same manner as the superior lateral sacral artery.

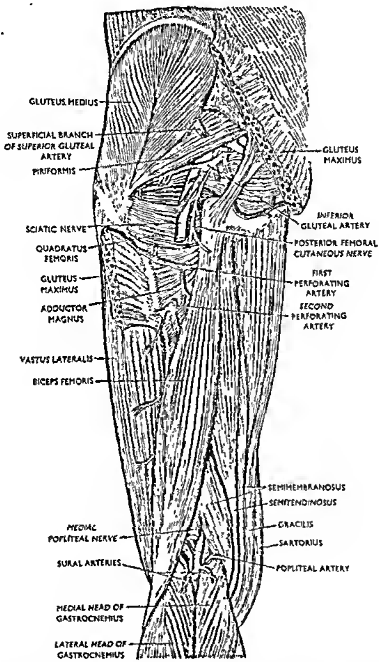

Fig. 632. The gluteal region, back of the thigh and a part of the upper leg have been exposed. *Note the positions of the arteries.*

From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

Superior gluteal artery. The superior gluteal artery is the largest branch of the internal iliac artery and arises from its posterior trunk. It at first lies between the lumbosacral nerve trunk and the first sacral nerve and then emerges out of the pelvic cavity through the greater sciatic foramen above the piriformis muscle. After

that it divides into superficial and deep branches. It is covered by the gluteus maximus muscle in the gluteal region.

The *superficial branch* enters into the deep surface of the gluteus maximus muscle and supplies this muscle; some of its branches pierce the gluteus maximus and anastomose with the branches of the inferior gluteal artery and the posterior branches from the lateral sacral artery.

The *deep branch* soon divides into superior and inferior branches. The superior branch runs along the upper border of the gluteus minimus to the anterior superior iliac spine and anastomoses with the deep circumflex iliac artery and with the ascending branch of the lateral circumflex femoral artery. The inferior branch crosses the gluteus minimus muscle obliquely and ends by anastomosing with the lateral circumflex femoral artery. One of its branches enters the trochanteric fossa and anastomoses with the inferior gluteal artery and the ascending branch of the medial circumflex femoral artery.

Inferior gluteal artery. It is the larger terminal branch of the anterior trunk of the internal iliac artery and passes downwards in front of the piriformis muscle and the sacral plexus of nerves and the internal pudendal artery. It then emerges out of the pelvic cavity through the greater sciatic foramen below the piriformis muscle. In the gluteal region it passes downwards along with the sciatic nerve and the posterior femoral cutaneous nerve and finally it is continued to the back of the thigh where it ends by anastomosing with the perforating branches from the arteria profunda femoris.

Branches: Inside the pelvic cavity.

(1) *Muscular.* Muscular branches in the pelvis supply the piriformis, levator ani and the coccygeus.
(2) *Vesical.* It supplies the fundus of the bladder, seminal vesicles and the prostate.
(3) *Branches supplying the fat around the rectum.*

Outside the pelvic cavity:

(1) *Muscular.* Muscular branches supply the gluteus maximus, hamstring muscles and the lateral rotators of the thigh. They anastomose with superior gluteal; obturator, internal pudendal and the medial circumflex femoral arteries.
(2) *Coccygeal branches.* They pierce the sacrotuberous ligament and supply the gluteus maximus and the structures attached to the back of the coccyx.
(3) *Arteria comitans nervi ischiadici.* It is a long slender branch which accompanies the sciatic nerve for a short distance and then penetrates into it.
(4) *Anastomosing branch.* It descends downwards and joins in the cruciate anastomosis at the lower part of the greater trochanter.
(5) *Articular branch.* It supplies the capsule of the hip joint and may arise from the anastomosing branch.
(6) *Cutaneous branch.* The cutaneous branches supply the skin of the buttock and the back of the thigh.

Femoral artery. *Course.* The femoral artery begins as a direct continuation of the external iliac artery from opposite the middle of the inguinal ligament and passes downwards and medially to the opening in the adductor magnus opposite the junction of the middle with the lower-third of the thigh and ends by passing into the popliteal fossa through its opening in the adductor magnus. Its upper part lies in the femoral triangle whereas its lower part lies in the sub-sartorial canal.

Relations in the femoral triangle:

Anteriorly:

(1) Skin, superficial and deep fasciae and superficial circumflex iliac veins.

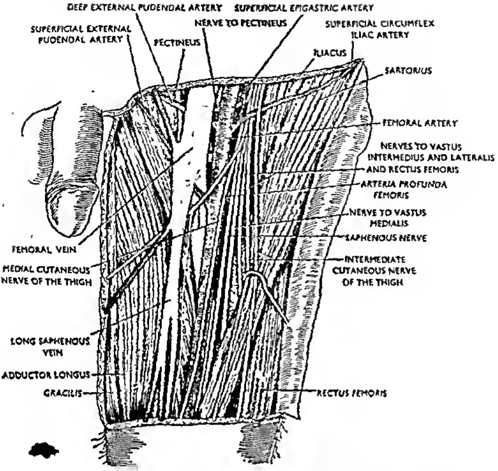

Fig. 633. The structures of the femoral triangle.
From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permision from the Prof. of Anatomy.

(2) Superficial inguinal lymph glands.
(3) Anterior layer of the femoral sheath.
(4) Femoral branch of the genitofemoral nerve—it lies at first in front of the artery in the lateral compartment of the femoral sheath and then passes to its lateral side.
(5) Medial cutaneous nerve of the thigh—it crosses the artery from lateral to the medial side opposite the apex of the femoral triangle.

Posteriorly:

(1) The posterior layer of the femoral sheath separates it from the psoas, pectineus, nerve to the pectineus and the adductor longus from above downwards and medially.
(2) The psoas separates it from the capsule of the hip joint.
(3) The femoral vein and the profunda vessels separate it from the pectineus and the adductor longus.

Laterally:

Femoral nerve lies on the lateral side of the femoral artery, being separated from it by the lateral wall of the femoral sheath. The saphenous nerve and the nerve to the vastus medialis both lie on the lateral side of the artery but the former is medial to the latter. The medial cutaneous nerve of the thigh lies at first laterally and then crosses in front of it to its medial side opposite the apex of the triangle.

Medially:

Femoral vein is its medial relation but opposite the apex of the femoral triangle the vein lies posterior to the artery.

Branches in the femoral triangle:

(1) Superficial circumflex iliac artery.
(2) Superficial epigastric.
(3) Superficial external pudendal.
(4) Deep external pudendal.
(5) Muscular.
(6) Arteria profunda femoris.

Development. The femoral artery is the continuation of a branch from the secondary umbilical artery proximal to the origin of the axial artery of the lower limb from it. The proximal portion of this branch forms the external iliac artery.

The primary umbilical artery which arises from the dorsal aorta migrates caudally to fuse with the fourth lumbar intersegmental artery (common iliac) and forms the secondary umbilical artery.

Anomalies. The external iliac artery, and its continuation, the *femoral artery*, may be too small to terminate into the arteria profunda femoris. When this condition exists the inferior gluteal artery follows the sciatic nerve to pass to the popliteal fossa and replaces the femoral artery. In rare cases the femoral artery may split into two trunks below the origin of the arteria profunda femoris and reunite again before passing into the popliteal fossa; occasionally the femoral artery may be joined with a vasa aberrans coming from the external iliac artery and thus there may be two femoral arteries in the upper part of the thigh. The arteria profunda femoris may be absent and the branches from it in such condition arise directly from the femoral. Occasionally the femoral artery may give origin to an abnormal artery, the *long saphenous artery* (normally present in many mammals) below the arteria profunda femoris and accompanies the saphenous nerve as far as the medial side of the foot.

(1) *Superficial circumflex iliac artery.* This is smallest of the superficial branches of the femoral artery and may arise by a common trunk with the superficial epigastric artery. It pierces the deep fascia above and lateral to the saphenous opening and passes upwards and laterally parallel to the inguinal ligament and lying a little distal to it. It becomes subcutaneous near the anterior superior iliac spine. It supplies the skin, superficial fascia and the superficial inguinal lymph glands and anastomoses with superior gluteal, lateral circumflex femoral and the deep circumflex femoral arteries.

(2) *Superficial epigastric.* It arises from the front of the femoral artery and becomes superficial by piercing the cribriform fascia. It passes upwards and medially and reaches the abdominal wall by crossing superficial to the inguinal ligament and then further ascends upwards and medially in between the two layers of the superficial fascia of the abdomen to the umbilicus where it ends by anastomosing with the branches of the inferior epigastric artery and also with the fellow of its opposite side. In its course it supplies the skin, superficial inguinal lymph glands and the subcutaneous tissue.

(3) *Superficial external pudendal.* It arises from the medial side of the femoral artery and pierces the cribriform fascia covering the saphenous opening and passes upwards and medially. It crosses superficial to the spermatic cord in the male and the round ligament of the uterus in the female. It is distributed in the skin of the suprapubic region, scrotum and penis in the male and in the female, labia and mons pubis. It anastomoses with the deep circumflex iliac and internal pudendal arteries.

(4) *Deep external pudendal.* It is a comparative larger branch and is more deeply and distally placed. It passes medially in front of the pectineus and the adductor longus deep to the fascia lata. It pierces the fascia lata at the medial side of the thigh and supplies the skin of the scrotum and perineum in the male and the labium majus in the female. It anastomoses with the scrotal or labial branches of the internal pudendal artery.

(5) *Muscular branches.* The muscular branches from the femoral artery supply the sartorius, vastus medialis and the adductor muscles of the thigh.

(6) *Arteria profunda femoris. Course.* The arteria profunda femoris arises from the postero-lateral aspect of the femoral artery about 1½ to 2 inches below the inguinal ligament. At first it runs downwards and laterally on the iliacus lying lateral to the femoral artery. Then it curves medially behind the femoral artery to reach the interval between the pectineus and the adductor longus. After that it descends downwards under cover of the adductor longus and lies successively upon the adductor brevis and the adductor magnus. Reaching the lower one-third of the thigh it pierces the adductor magnus and ends by anastomosing with the superior muscular branch of the popliteal artery.

Relations:

Anteriorly:

(1) Femoral vessels—The profunda vein separates it from the femoral vessels as it crosses posterior to them.
(2) Profunda vein.
(3) Adductor longus.

Posteriorly: In order from above downwards and medially.

(1) Iliacus.
(2) Pectineus.
(3) Adductor brevis.
(4) Adductor magnus.

Laterally: Vastus medialis.

Branches:

(1) Lateral circumflex femoral.
(2) Medial circumflex femoral.
(3) Perforating.

(1) **Lateral circumflex femoral artery.** It arises from the lateral aspect of the arteria profunda femoris close to its origin and passes laterally in front of the vastus intermedius and behind the sartorius and rectus femoris and accompanies the muscular branches of the femoral nerve. It divides into ascending, descending and transverse branches.

The *ascending branch* runs upwards behind the tensor fasciae latae to the region of the anterior superior iliac spine where it ends by anastomosing with the deep circumflex iliac and the superior gluteal arteries. It provides muscular branches which supply the rectus femoris, gluteus medius et minimus and an articular branch which passes in between the two limbs of the iliofemoral ligament and supplies the hip joint.

The *descending branch* is the largest of all and is usually multiple. They descend downwards in company with the nerve to the vastus lateralis and following the anterior margin of the vastus lateralis they reach the upper part of the knee joint where one of its branches pierces the vastus lateralis muscle and ends by anastomosing with the superior lateral genicular branch of the popliteal artery. In its course it supplies the adjacent muscles and its muscular branches anastomose with the perforating arteries.

The *transverse branch* is the smallest of all and passes laterally in front of the vastus intermedius and pierces the vastus lateralis. One of its branches pierces through the insertion of the gluteus maximus and reaches the lower part of the greater trochanter where it anastomoses with the transverse branch of the medial circumflex femoral artery, inferior gluteal artery and the first perforating artery to form the *cruciate anastomosis*.

(2) **Medial circumflex femoral artery.** It is smaller than the lateral circumflex femoral artery and arises from the postero-medial aspect of the arteria profunda femoris. It winds round the medial aspect of the femur and at first passes

between the psoas and pectineus, then between adductor brevis and obturator externus and finally it reaches the intermuscular space between the quadratus femoris and the upper part of the adductor magnus where it divides into ascending and transverse and acetabular branches.

The *ascending branch* runs upwards along the tendon of the obturator externus in front of the quadratus femoris and reaches the trochanteric fossa where it ends by anastomosing with the gluteal arteries.

The *transverse branch* passes to the lower part of the greater trochanter and takes part in the formation of the cruciate anastomosis.

The *acetabular branch* arises from it at the upper border of the adductor brevis and then enters into the acetabular fossa in company with the acetabular branch of the obturator artery behind the transverse acetabular ligament and supplies the structures in the acetabular fossa.

(3) **Perforating branches.** The perforating branches are so named because they perforate the adductor magnus and reach the back of the thigh. They are usually three in number and each passes through an osseo-aponeurotic opening formed by the arched tendinous fibres of insertion of the adductor magnus and the linea aspera of the femur. They give out muscular, cutaneous and anastomosing branches and becoming much reduced in size they pass deep to the short head of the

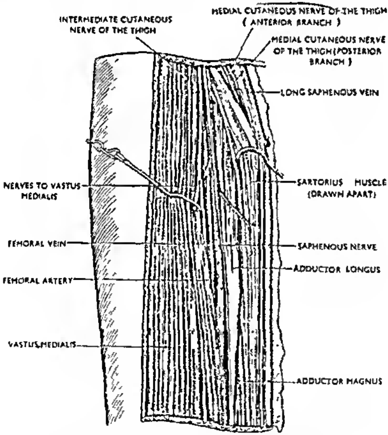

Fig. 634. The femoral artery in the adductor canal.
From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

biceps femoris, pierce the lateral intermuscular septum and finally enter into the vastus lateralis. Each perforating artery divides into ascending and descending branches The ascending branch of the first perforating artery joins in the cruciate

anastomosis while its descending branch anastomoses with the second perforating artery.

The second perforating artery anastomoses with the first and third perforating arteries by its ascending and descending branches. The third perforating artery anastomoses below with the terminal end of the arteria profunda femoris which is often called the fourth perforating artery and with the superior muscular branch of the popliteal artery. The perforating arteries supply the muscles on the back and form a chain of anastomoses on the back of the thigh.

Relations of the femoral artery in the adductor canal:

Anteriorly:

(1) Skin, superficial and the deep fasciae.
(2) Sartorius.
(3) Sub-sartorial plexus of nerves.
(4) Aponeurotic roof of the canal.
(5) Saphenous nerve. It crosses superficial to the artery from lateral to the medial side.

Posteriorly:

(1) Femoral vein (in the upper part of the canal and posterolateral to the artery in the lower part of the canal).
(2) Adductor longus et magnus.

Laterally:

(1) Vastus medialis muscle.
(2) Nerve to the vastus medialis.

Medially:

(1) Adductor longus.
(2) Adductor magnus.

Branches in the adductor canal:

(1) Muscular.
(2) Descending genicular.

(1) *Muscular branches.* They supply the muscles on the floor of the adductor canal.

(2) *Descending genicular.* It arises from the femoral artery immediately before it passes through the opening in the adductor magnus. After giving a saphenous branch it runs downwards through the substance of the vastus medialis to reach the medial aspect of the knee joint where it anastomoses with the superior medial genicular artery. It supplies muscular branches to the vastus medialis and adductor magnus and an articular branch which joins in the anastomosis around the knee joint and supplies the same.

The saphenous branch of the descending genicular artery pierces the aponeurotic roof of the adductor canal in company with the saphenous nerve. It descends between the sartorius and gracilis to the medial side of the knee joint and supplies the skin over the upper and medial part of the leg and finally anastomoses with the medial inferior genicular artery.

Cruciate anastomosis below the greater trochanter of the femur. An arterial arch is formed at the lower part of the greater trochanter of the femur by the union of the transverse branches from the lateral and the medial circumflex femoral arteries. This is joined from below by the ascending branch of the first perforating artery and is joined from above by the anastomosing branch of the inferior gluteal artery. The anastomosis thus formed at the lower part of the greater

trochanter of the femur resembles a St. Andrew's cross and is called as the cruciate anastomosis.

The perforating branches of the arteria profunda femoris anastomose with one another by descending and ascending branches, the fourth perforating artery anastomosing below with the superior muscular branch of the popliteal artery. In the gluteal region the branches of the lateral and the medial circumflex femoral arteries anastomose with the branches of the gluteal arteries. Thus an important chain of anastomosis extends from the gluteal region to the popliteal fossa. They are formed as follows:

(1) Gluteal arteries anastomose with the branches of the lateral and the medial circumflex femoral arteries.

(2) The circumflex femoral arteries anastomose with the perforating branches of the arteria profunda femoris.

(3) The fourth perforating artery anastomoses with the superior muscular branch of the popliteal artery.

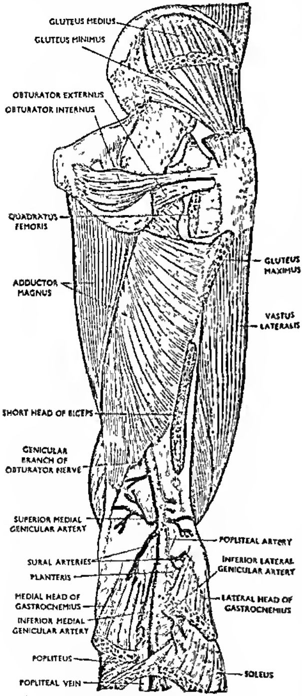

Fig. 635. The deep dissection of the back of the thigh and the gluteal region. Note the popliteal artery and its branches.

Popliteal artery. *Course.* The popliteal artery is the direct continuation of the femoral artery and begins from the opening of the femoral artery in the adductor magnus opposite the junction of the middle-third with the lower-third of the thigh. At first it runs downwards and laterally to the intercondylar fossa of the femur, then it runs vertically downwards to the lower border of the popliteus where it ends by dividing into the anterior and the posterior tibial arteries.

Relations. Anteriorly, from above downwards, it is related to the popliteal surface of the femur, back of the knee joint and the fascia covering the popliteus.

Posteriorly and above, it is overlapped by the semimembranosus. *Posteriorly* and *below*, it is covered by the two heads of the gastrocnemius.

In the middle of the fossa it is covered only by the skin, superficial fascia, deep fascia and some quantity of fat. In this situation it is crossed from lateral to medial side *by the medial popliteal nerve and the popliteal vein; the nerve being separated* from the artery by the vein. The articular branch of the obturator nerve (post. division) lies posterolateral to the artery.

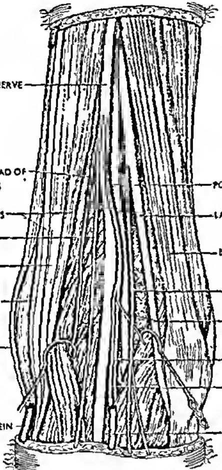

Fig. 636. The dissection of the popliteal fossa.
From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

Laterally and above it is in relation to the medial popliteal nerve, popliteal vein, the biceps femoris and the lateral condyle of the femur. *Laterally and below* it is related to the lateral head of the gastrocnemius.

Medially and above it is in relation to the semimembranosus and the medial condyle of the femur. *Medially and below* it is in relation to the medial popliteal nerve, popliteal vein and the medial head of the gastrocnemius.

Branches:

Cutaneous.

Muscular:

(i) Superior.
(ii) Sural.

Terminal:

(i) Anterior tibial.
(ii) Posterior tibial.

Genicular:

(i) Superior:
(a) Lateral.
(b) Medial.

(ii) Middle.

(iii) Inferior:
(a) Lateral.
(b) Medial.

Development. The *proximal portion* of the popliteal artery is formed by that persisting portion of the axial artery which intervenes between its arteria communicans superior and the upper border of the popliteus muscle. Its distal portion is formed by the fusion of the proximal part of the primitive posterior tibial and the peroneal arteries.

Anomalies. In rare cases the popliteal artery may arise as a direct continuation of the inferior gluteal artery (persistent axial artery). The popliteal artery may occasionally divide into three terminal branches, anterior tibial, posterior tibial and peroneal; the sural branch of the popliteal artery may enlarge sufficiently to form a large artery, the *short saphenous artery* which may accompany the sural nerve to the lateral aspect of the foot.

Cutaneous branches arise either from the popliteal artery or from some of its branches and descend between the two heads of the gastrocnemius and after piercing the deep fascia they accompany the short saphenous vein and are distributed to the skin on the back of the leg.

Muscular branches are superior and sural. (i) The superior muscular branches arise from the artery immediately below the superior angle of the fossa and end by supplying the adjoining muscles and by anastomosing with the fourth perforating branch of the arteria profunda femoris. (ii) The sural branches are two large collateral arteries that pierce the adjoining muscles (gastrocnemius, soleus and plantaris) and end by supplying them.

Genicular branches are superior, middle and inferior. (i) The superior genicular arteries are two in number, each arising from either side of the artery immediately above the knee joint. Each artery winds round the corresponding condyle and divides into branches which end in the arterial anastomosis in front of the knee joint. (ii) The middle genicular artery arises from it opposite the middle of the knee joint and pierces the oblique posterior ligament to supply the structures in the intercondylar fossa. (iii) The inferior genicular arteries are two collateral branches arising from it below the corresponding condyle of the tibia to end into the arterial anastomosis in front of the knee joint.

The popliteal artery divides into its terminal branches (the anterior and posterior tibial arteries) at the lower border of the popliteus.

Arterial anastomosis around the knee joint. The anastomosis around the knee joint is placed in front of the knee joint and consists of arterial arches which surround the patella and the contiguous margins of the condyles of the tibia and the femur. It consists of superficial and deep networks and is formed by the different genicular arteries and by the descending branch of the lateral circumflex femoral artery. The superficial network is ill-defined and lies in the subcutaneous tissue in front of the patella and behind the ligamentum patella. The deep set of network forms distinct arches which lie both above and below the patella and surround the condyles of the tibia and the femur close to their articular surfaces.

Superficial network forms three ill-defined arterial arches of which one lies in the subcutaneous tissue in front of the patella and two of them lying in the fat behind the ligamentum patellae.

Deep network. It consists of four distinct arterial arches of which two are placed above the patella and the two below the patella; the transverse arches are again connected with one another by vertical branches. The arrangement of the network is as follows:

(1) The descending branch of the lateral circumflex femoral artery anastomoses with the descending genicular branch of the femoral artery and forms an arch which lies behind the quadriceps femoris tendon and above the patella.

(2) The second arch is formed by the descending genicular artery and the *superior lateral genicular artery* and lies above the patella and in front of the quadriceps femoris tendon.

(3) The third arch is formed by the union of the superior medial genicular artery and the inferior lateral genicular artery and lies behind the ligamentum patellae.

(4) The fourth arch also lies behind the ligamentum patellae and is formed by the anastomosis of the inferior medial genicular artery, the anterior *tibial recurrent*, and *the circumflex fibular* branch of the posterior tibial artery.

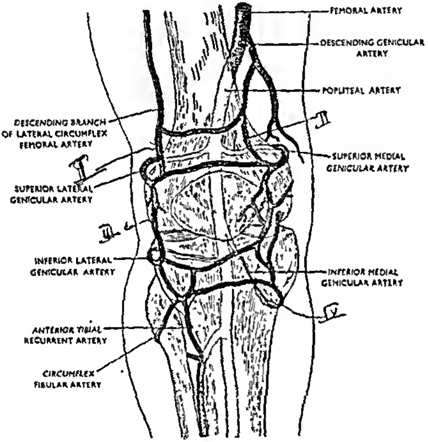

Fig. 637. The anastomosis around the knee joint.

Anterior tibial artery. *Course and relations.* The anterior tibial artery is one of the terminal branches of the popliteal artery and begins in the back of the leg opposite the lower border of the popliteus. It runs forwards between the two heads of the tibialis posterior and enters the front of the leg through the opening in the interosseous membrane. At first it lies on the interosseous membrane, then it gradually inclines medially and in the lower-third of the leg it rests on the lower part of the tibia and reaching the front of the ankle joint it is continued over the dorsum of the foot as the arteria dorsalis pedis. In the upper two-thirds of the leg it is deeply placed and lies at first between the tibialis anterior and the extensor hallucis longus. Opposite the lower-third of the leg it is superficial being covered only by the skin and the fascia; in this situation it is crossed by the tendon of the extensor hallucis longus from lateral to the medial side and intervenes between it and the extensor digitorum longus. The anterior tibial nerve lies at first lateral to it, then in front of it and again lies on the lateral

side of the artery in the lower part of the leg. The artery is accompanied by a pair of venae comitantes.

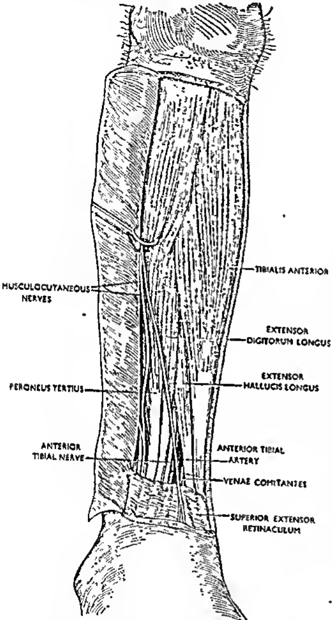

Fig. 638. The dissection of the antero-lateral region of the leg.
Note the relations of the anterior tibial artery with the extensor tendons.
From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

Branches:

(1) Anterior tibial recurrent.
(2) Posterior tibial recurrent.
(3) Muscular.
(4) Anterior medial malleolar.
(5) Anterior lateral malleolar.

Development. The anterior tibial artery is formed by the arteria communicans medius, the persisting short segment of the axial artery below the popliteus, the perforating branch of the axial artery in this situation and by the primary anterior tibial artery from the ventral capillary plexus.

Anomalies. The anterior tibial artery may be absent and replaced by the branches from the posterior tibial and the peroneal arteries. The terminal part of the dorsalis pedis may occasionally replace the lateral plantar artery.

(*a*) *Anterior tibial recurrent.* It arises from it as soon as it reaches the front of the leg and ascends upwards through the fibres of the tibialis anterior and finally ends in the anastomosis in front of the knee joint.

(*b*) *Posterior tibial recurrent.* It arises from the anterior tibial artery in the posterior compartment of the leg and ascends upwards to join in the arterial anastomosis around the knee joint.

(*c*) *Muscular.* They are numerous and supply the muscles in this region.

(*d*) *Anterior medial malleolar.* It arises from the anterior tibial artery immediately above the ankle joint and passes medially behind the tendons of the extensor hallucis longus and tibialis anterior and ends by anastomosing with the branches of the posterior tibial arteries.

(*e*) *Anterior lateral malleolar.* It arises from the anterior tibial artery immediately above the ankle joint and passes laterally beneath the extensor digitorum longus and

oneus tertius tendons to reach the lateral surface of the lateral malleolus where nds by anastomosing with the perforating branch of the peroneal artery and the ral tarsal artery.

Arteria dorsalis pedis. *Course.* It begins as a direct continuation of the erior tibial artery opposite the mid-point between the lateral and the medial lleoli and passes forwards to the proximal part of the first intermetatarsal space. en by passing between the two heads of the first dorsal interosseous muscle it ends anastomosing with the lateral plantar artery to complete the plantar arch.

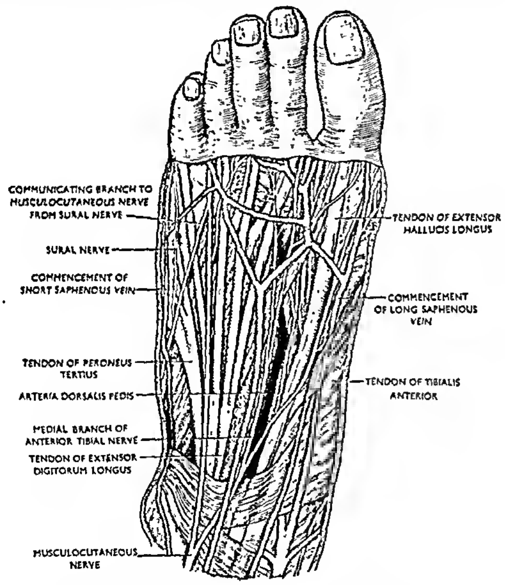

Fig. 639. The dissection of the dorsum of the left foot.
Note the relations of the arteria dorsalis pedis.
From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

Relations:

Anteriorly. It is covered by the skin, superficial fascia and the inferior extensor tinaculum. The first tendon of the extensor digitorum brevis crosses in front it just before it dips into the sole of the foot.

Posteriorly. It lies successively upon the articular capsule of the ankle joint, talus, navicular, intermediate cuneiform bones and the ligaments connecting these three bones.

Laterally. It is related to the first tendon of the extensor digitorum longus and the medial branch of the anterior tibial nerve.

Medially. It is related to the extensor hallucis longus tendon.

Branches:

(1) Tarsal:
  (*a*) Lateral.
  (*b*) Medial.

(2) Arcuate—forms an arch on the dorsum of the foot.
(3) First dorsal metatarsal.

(1) *Tarsal branches.* They are two in number, one medial and one lateral; the medial branch arises from its medial side and passes to the medial margin of the foot where it ends by anastomosing with the branches from the medial plantar artery. The lateral branch passes laterally beneath the extensor digitorum brevis to reach the lateral margin of the foot where it ends by anastomosing with the branches from the peroneal, anterior lateral malleolar and lateral plantar arteries.

(2) *Arcuate branch.* It arises from its lateral side opposite the base of the first metatarsal bone and passes laterally beneath the extensor digitorum brevis to reach the lateral margin of the foot where it ends by anastomosing with the branches of the lateral plantar artery. In its course it forms an arch with a forward convexity and from its convex margin it gives out three dorsal matatarsal arteries (2,3 and 4), one for each of the lateral three interosseous spaces. Each dorsal metatarsal artery reaching cleft between the toes divides into two collateral arteries for the digits. From the lateral extremity of the arch a twig passes to the lateral side of the little tow.

(3) *First dorsal metatarsal artery.* It arises from the dorsal is pedis artery opposite the point from where it turns plantarwards. It provides a twig which supplies the medial side of the great toe and then divides into two collateral branches which supply the contiguous sides of the first and the second toes.

Posterior tibial artery. *Course.* The posterior tibial artery commences at the bifurcation of the popliteal artery opposite the lower border of the popliteus muscle. It descends downwards and medially to reach the interval between the medial malleolus and the medial tubercle of the calcaneum where it lies beneath the flexor retinaculum and finally divides into medial and lateral plantar arteries behind the origin of the abductor hallucis muscle.

Relations. It lies successively upon the tibialis posterior, flexor digitorum longus, lower end of the tibia and the back of the ankle joint. Above it is covered by the gastrocnemius, plantaris, soleus and the deep transverse fascia of the leg; below it is covered by the flexor retinaculum and the abductor hallucis; in the intermediate position (lower-third of the leg) it is covered only by the skin and the fasciae and in this situation it runs at a distance of about one inch in front of the tendo-calcaneus. The posterior tibial nerve at first lies on its medial side, then crosses posterior to it to gain its lateral side. Behind the flexor retinaculum, medially it is related to the tendons of the flexor digitorum longus and the tibialis posterior, and laterally, to the posterior tibial nerve and the tendon of the flexor hallucis longus. The posterior tibial vein lies in close contact with the artery.

Development. The posterior tibial artery represents the primitive posterior tibial branch of the axial artery of the lower limb.

Anomalies. The posterior tibial artery may be absent or too small. Its place is taken over by the branches from the peroneal artery. The peroneal branch of the posterior tibial artery may arise directly from the popliteal or it may arise in a common trunk with the anterior tibial artery.

Branches:

(1) *Circumflex fibular.* It joins in the anastomosis around the knee joint.

(2) *Peroneal artery. Course and relations.* The peroneal artery arises from the posterior tibial artery about one inch below the lower border of the popliteus muscle and passes downwards and laterally to the medial crest of the fibula and then runs vertically downwards along the medial crest to the back of the inferior tibio-fibular joint where it ends by dividing into calcaneal branches.

At its origin it is covered by the soleus and the deep transverse fascia of the leg and then as it passes along the medial crest of the fibula it lies within a fascial canal which intervenes between the tibialis posterior in front and the flexor hallucis longus behind.

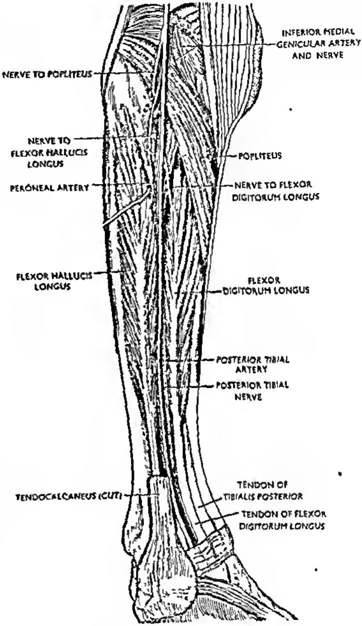

Fig. 640. The deep muscles of the left leg together with the posterior tibial artery and nerve.
From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

Branches:

(*a*) Muscular branches—They supply the adjacent muscles.

(*b*) Nutrient artery to the fibula.

(*c*) Perforating branch—It perforates the interosseous membrane about 2 inches above the lateral malleolus and anastomoses with the anterior lateral malleolar artery.

(*d*) Communicating—It arises from the peroneal artery about 2 inches above the lower end of the tibia and ends by anastomosing with the communicating branches from the posterior tibial artery.

(*e*) Calcaneal or terminal—They pass to the back and lateral aspect of the heel where they anastomose with the anterior lateral malleolar and calcaneal branches of the posterior tibial artery.

(3) *Muscular.* Muscular branches supply the deep muscles of the back and the soleus.

(4) *Nutrient.* It enters the tibia through the nutrient foramen below the soleal line.

(5) *Communicating.* It joins the communicating branch of the peroneal artery by passing deep to the flexor hallucis longus about 2 inches above the lower end of the tibia.

(6) *Medial malleolar.* It ends in the medial malleolar network.

(7) *Calcaneal.* The calcaneal branch pierces the flexor retinaculum and anastomoses with the calcaneal branches of the peroneal artery.

(8) *Medial plantar.* It is one of the terminal branches and is distributed to the sole of the foot along with the medial plantar nerve. Reaching the space between the abductor hallucis and the flexor digitorum brevis it divides into branches and becomes much reduced in size. It supplies the adjacent muscles and gives three super-ficial digital branches which join with the 1st, 2nd and 3rd plantar metatarsal arteries and also supplies one for the medial side of the great toe.

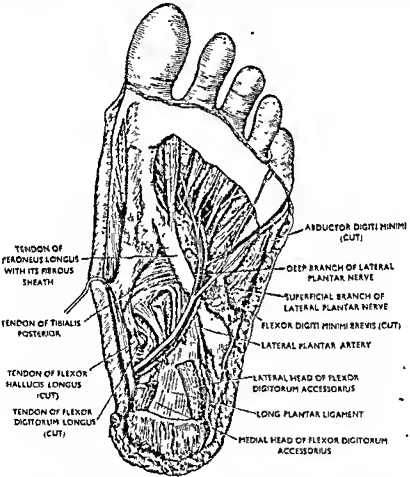

Fig. 641. The deep dissection of the sole of the right foot.
Note the formation of the plantar arch and its relations.
From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

(9) *Lateral plantar artery.* The lateral plantar artery is the larger terminal branch of the posterior tibial artery and begins from under cover of the abductor hallucis and passes laterally to reach the interval between the flexor digitorum brevis and the abductor digiti minimi; the lateral plantar nerve accompanies it on its medial side. Then accompanying the deep branch of the lateral plantar nerve it courses

to the medial side of the foot beneath the oblique head of the adductor hallucis and reaches the first interosseous space where it ends by anastomosing with the arteria dorsalis pedis to complete the plantar arch.

Plantar arch. It is the direct continuation of the lateral plantar artery and begins from opposite the level of the base of the fifth metatarsal bone and extends medially to the proximal part of the first interosseous space where by anastomosing with the arteria dorsalis pedis it completes the plantar arch. The arch lies deep to the oblique head of adductor hallucis and in its course the convexity of the arch is directed forwards. The following are the branches from the arch:

(1) *Perforating branches.* They are three in number and each ascends upwards between the two heads of the second, third and the fourth dorsal interosseous muscles respectively and end by anastomosing with the corresponding dorsal metatarsal arteries.

(2) *Plantar metatarsal arteries.* They are four in number and each runs forwards between two metatarsal bones with the interosseous muscle and reaching the cleft between the digits divides into two plantar digital arteries which supply the adjacent sides of the toes. Near the point of division each plantar metatarsal artery gives out the anterior perforating branch which anastomoses with the dorsal metatarsal artery. The first plantar metatarsal artery arises from the point of union of the lateral plantar artery and the arteria dorsalis pedis. It gives out a digital branch which supplies the medial side of the great toe. The digital branch supplying the lateral side of the little toe is derived from the lateral plantar artery from opposite the base of the fifth metatarsal bone.

THE VEINS

THE VEINS OF THE SCALP

The veins draining the scalp consist of supratrochlear, supraorbital, superficial temporal, posterior auricular and occipital veins. The supraorbital and the supratrochlear veins unite to form the facial (anterior facial) vein, the superficial temporal and the maxillary (internal maxillary) veins unite to form the retromandibular (posterior facial) vein; the posterior auricular vein unites with the posterior division of the retromandibular vein to form the external jugular vein. The occipital vein ends into the sub-occipital venous plexus.

The supratrochlear vein. It begins in a venous network over the region of the forehead which becomes confluent to form a single vein close to the median plane. The single vein thus formed descends downwards in parallel with the fellow of the opposite side to the root of the nose where they are joined together by a transverse venous channel known as the *nasal arch*. Each vein then descends to the medial angle of the orbit where it unites with the supraorbital vein to form the *facial* (anterior facial) *vein*. The venous network at the origin of the supratrochlear vein communicates with the frontal tributaries of the superficial temporal vein.

The supraorbital vein. It begins in the region of the zygomatic process of the frontal bone where it communicates with the superficial and the middle temporal veins. It then runs transversely medialwards along the upper part of the supraorbital margin of the frontal bone under cover of the orbicularis oculi and reaching the medial angle of the orbit it unites with the supratrochlear vein to form the *facial vein*.

The superficial temporal vein. It begins in a plexiform network on each side of the vertex of the skull which is drained by two veins, *anterior* and *posterior*. The anterior and the posterior veins descend downwards and unite together above the zygomatic arch to form the superficial temporal vein. It is then joined by the middle temporal vein and descends further downwards by crossing the posterior root of the zygomatic process of the temporal bone and enters into the substance of the

parotid gland where it unites with the maxillary vein to form the retromandibular (posterior facial) vein. The venous network at the commencement of the superficial temporal vein communicates with the fellow of its opposite side, with the supraorbital, supratrochlear and posterior auricular veins and with the occipital vein.

Tributaries:

(1) Some veins that drain the parotid gland.
(2) Anterior auricular vein draining the auricle.
(3) Articular veins draining the temporomandibular joint.
(4) Transverse facial vein draining the face.
(5) Middle temporal vein draining the temporal region and the lateral part of the eye lids.

The posterior auricular vein. It begins as a venous plexus on each side of the head which converges to a single vein which descends behind the ear and reaching the lower end of the parotid gland it joins the posterior division of the retromandibular vein to form the external jugular vein. The stylomastoid vein and some veins from the posterior part of the auricle form its tributaries.

The occipital vein. It also beings in a plexiform network on the back of the head and by piercing through the origin of the trapezius muscle it enters into the sub-occipital triangle where it ends by joining with the deep cervical and vertebral veins to form the *sub-occipital venous plexus.* It may, however, terminate into the posterior auricular, internal or external jugular vein.

It communicates with the superior sagittal sinus by the parietal emissary vein and with the transverse sinus by the mastoid emissary vein.

THE VEINS OF THE INFRATEMPORAL REGION

The pterygoid venous plexus. As the name implies it is a venous plexus situated between the pterygoid muscles but it also intervenes between the latter muscles and the temporalis muscle in the infratemporal region of the skull. The plexus is formed by the confluence of the spheno-palatine, pterygoid, deep temporal, masseteric, buccal, dental, middle meningeal, greater palatine veins and the inferior ophthalmic vein. Thus all the above veins become confluent to form the maxillary vein.

The pterygoid venous plexus communicates with the (anterior) facial vein through the *deep facial vein* and with the cavernous sinus through the emissary veins that pass through foramen ovale, lacerum and the emissary sphenoidal foramen and through the inferior ophthalmic vein.

The Maxillary (internal maxillary) **vein.** It is a short venous channel that accompanies the first part of the maxillary artery and is formed by the union of the veins of the pterygoid venous plexus. It intervenes between the sphenomandibular ligament and the neck of the mandible and runs backwards into the parotid gland where it unites with the superficial temporal vein to form the retromandibular (posterior facial) vein.

The retromandibular (posterior facial) **vein.** It is formed by the union of the maxillary and the superficial temporal veins within the substance of the parotid gland where it lies between the facial nerve superficially and the external carotid artery deeply. It ends by dividing into anterior and posterior branches. The anterior branch joins with the facial vein whereas the posterior branch joins with the posterior auricular vein to form the external jugular vein.

THE DIPLOIC VEINS

The **diploic veins** occupy the diploie of the cranial bones and are characterised by their thin walls, irregular outline with pouch-like dilatation and free communi-

cation between each other and with the veins both inside and outside the cranium. They have no valves and structurally their walls consist of a single layer of endothelium supported externally by a layer of elastic tissue. The diploie of the cranial bones begin to appear at about the second year after birth and subsequently the diploic veins begin to appear and, therefore, the diploic veins are absent in the skulls of the children below two years.

Situation and number. There are usually five chief veins on each side: frontal, two anterior temporal, one posterior temporal, and one occipital diploic vein and a few smaller veins.

Frontal diploic vein. It is lodged within the diploie of the frontal bone and ends by opening in the supraorbital vein by passing through a small opening in the roof of the supraorbital notch. It communicates with the superior sagittal sinus and with the cavernous sinus through the supraorbital vein and its communication with the superior ophthalmic vein.

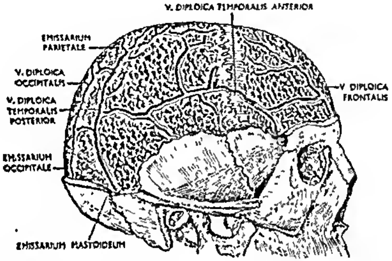

Fig. 642. The diploic veins of the skull.
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Anterior temporal diploic veins. The two anterior temporal deploic veins descend downwards, one in front of and the other behind the coronal suture and end into the sphenoparietal sinus by piercing through the greater wing of the sphenoid. They may also end into the anterior deep temporal vein.

Posterior temporal diploic vein. It is lodged within the diploie of the parietal bone and descends downwards to the mastoid region where it pierces through the inner table to terminate into the transverse sinus.

Occipital diploic vein. It is the largest diploic vein which is confined within the occipital bone and it ends by opening into either the occipital vein or into the transverse sinus.

Smaller diploic veins. They open into the venous lacunae in association with the superior sagittal sinus by piercing through the inner table of the parietal bone.

THE VEINS OF THE NECK

External jugular vein. The external jugular vein is the largest of the superficial veins of the neck and drains the blood from the exterior of the cranium, deep part of the face and the superficial part of the neck.

It is formed by the union of the posterior auricular and the posterior division of the retromandibular (posterior facial) veins at or below the level of the angle of the mandible. Then it descends obliquely backwards and downwards across the sternocleidomastoid muscle and reaches the subclavian triangle where it pierces the deep fascia and ends by opening into the subclavian vein. Its courses in the neck can be represented by a line drawn from the angle of the mandible to the middle of the clavicle. It is covered by skin, superficial fascia and platysma. It is separated from the sternocleidomastoid muscle by the investing layer of the deep cervical fascia. In its course downwards over the sternocleidomastoid muscle it crosses the transverse (anterior) cutaneous nerve of the neck, and the great auricular nerve runs upwards in parallel to its upper part. Near its termination, where it pierces the deep cervical fascia, it is adherent to the latter at the circumferential margin of the opening in the same.

It is provided with two pairs of valves, the lower one is situated immediately above its termination into the subclavian vein and the upper one being placed at a distance of about $1\frac{1}{2}$ inches above it. In between these two pairs of valves the vein presents a dilatation known as the *sinus of the external jugular vein*.

Tributaries:

(1) Posterior external jugular vein.
(2) Transverse cervical.
(3) Suprascapular.
(4) Anterior jugular.
(5) Communicating to the internal jugular.
(6) Occipital (sometimes).
(7) Cephalic (rarely).

The *transverse cervical* and *suprascapular veins* accompany the corresponding arteries at the root of the neck.

The posterior external jugular vein. It begins in the region of the back of the head and receives tributaries from the skin and superficial muscles of the postero-superior part of the neck and it ends by opening into the middle of the posterior border of the external jugular vein.

The anterior jugular vein. The anterior jugular veins are arranged in pairs, one on each side of the median plane, in the region of the front of the neck. Each anterior jugular vein begins in the region of the submental triangle by the union of several smaller veins from the submandibular region and descends vertically downwards between the anterior border of the sternocleidomastoid and the middle line to the root of the neck and is covered by the skin, superficial fascia and platysma. At the root of the neck it turns laterally and passes in front of the sternohyoid and sternothyroid, and behind the sternocleidomastoid muscles and ends by opening into the external jugular vein just before its termination. It may, however, terminate into the subclavian vein in some cases. At the root of the neck opposite the suprasternal notch the two anterior jugular veins are communicated together by a transverse venous channel known as the *jugular arch*. Each anterior jugular vein communicates also with the internal jugular vein.

Some laryngeal veins, a vein from the thyroid gland and some subcutaneous veins in the region of submandibular triangle form its tributaries.

Internal jugular vein. The internal jugular vein begins as a direct continuation of the sigmoid sinus at the base of the skull in the posterior compartment of the jugular foramen. At its origin it forms a dilatation known as the *superior bulb* which is contained in the jugular fossa of the temporal bone and is separated from the floor of the tympanic cavity by a thin osseous lamina. The vein next runs downwards through the neck being contained in the carotid sheath and reaching behind the sternal end of the clavicle it unites with the subclavian vein to form the brachiocephalic vein. Near its termination it forms a second dilatation, the *inferior bulb* of the internal jugular vein.

Relations. Posteriorly, the vein is related to the transverse processes of the cervical vertebrae, the rectus capitis lateralis, longus capitis, levator scapulae, cervical plexus of nerves, scalenus anterior muscle and the phrenic nerve, and at the root of the neck, it is related posteriorly to the first part of the subclavian artery, origin of the vertebral artery and the thyrocervical trunk. *On the left side* the thoracic duct forms an additional posterior relation. The transverse cervical and suprascapular arteries intervene between it and the scalenus anterior muscle.

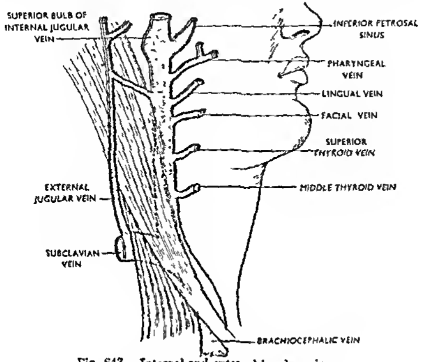

Fig. 643. Internal and external jugular veins. (Semi-diagrammatic).
Note the tributaries of the internal jugular vein.

Antero-medially, immediately below the skull, are the internal carotid artery and the last four cranial nerves; in the rest of its extent it is in relation, medially, first to the internal and then to the common carotid artery. The vagus nerve lies *posteromedial* to it.

Superficially, the internal jugular vein is covered by the sternocleidomastoid muscle throughout its entire extent; close to its upper end it is crossed by the styloid process, the stylopharyngeus and stylohyoid muscles and the posterior belly of the digastric. In the lower part of the neck it is crossed by the inferior belly of the omohyoid muscle and covered by the sternohyoid and the sternothyroid muscles, all of which lie under cover of the sternocleidomastoid muscle. In between the digastric and omohyoid it is crossed by the nervus descendents cervicalis from the second and the third cervical nerves. Opposite the transverse process of the atlas it is crossed by the accessory nerve and the occipital and posterior auricular arteries. The anterior jugular vein passes laterally in front of it being separated from it by the sternohyoid and sternothyroid muscles. The deep cervical lymph nodes lie along the course of the vein mainly on its superficial aspect.

Tributaries:

(1) Inferior petrosal sinus.
(2) A vein from the cochlea.
(3) Pharyngeal.
(4) Facial.
(5) Lingual.
(6) Occipital.
(7) Superior thyroid.
(8) Middle thyroid.

The thoracic duct opens into the angle of junction between the left subclavian and the left internal jugular veins and the right lymphatic duct opens into the angle of union between the right subclavian and the right internal jugular veins.

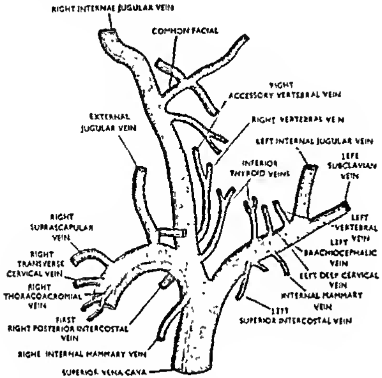

Fig. 644. The great veins of the head and neck and the superior extremity with their tributaries (schematic).

Inferior petrosal sinus. It is the first tributary of the internal jugular vein and comes out of the cranial cavity through the anterior part of the jugular foramen and runs downwards and backwards crossing the 9th, 10th and the 11th cranial nerves and finally terminates into the superior bulb of the internal jugular vein.

Cochlear vein. It drains the internal ear and comes out through the opening in the floor of the triangular depression on the inferior surface of the petrous part of the temporal bone.

Pharyngeal veins. They drain the pharyngeal venous plexus on the outer wall of the pharynx and also receive the vein of the pterygoid canal and open into the internal jugular vein.

The facial (anterior facial) *vein. Formation.* It is formed at the root of the nose on the medial angle of the orbit by the union of the supratrochlear and the supra-orbital veins.

Course and relation. After its formation at the root of the nose it lies superficial to the facial artery and descends downwards and backwards to the lower margin of the orbital opening. Then it descends further downwards and backwards across the cheek lying at a considerable distance posterior to the facial artery and passes deep to the zygomaticus major, risorius and platysma and reaches the anterior border of the masseter muscle. Then it crosses superficial to the antero-inferior part of the masseter muscle and the body of the mandible to reach its lower border where it comes into intimate relation with the facial artery and lies posterior to it. Then it runs obliquely downwards and backwards on the inferior surface of the submandi-

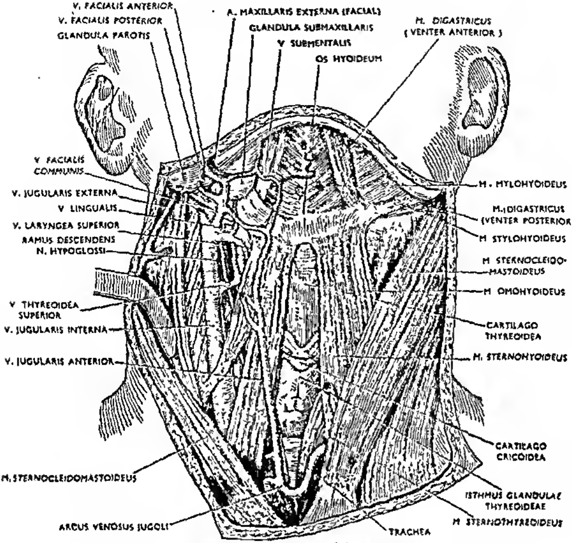

Fig. 645. The great vessels of the neck.
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bular gland and then crosses superficial to the digastric and stylohyoid muscles, the loop of the lingual artery, the hypoglossal nerve and the external and the internal carotid arteries and finally it ends by opening into the internal jugular vein close to the greater cornu of the hyoid bone. In its course in the neck it is covered by the platysma muscle and is joined by the anterior division of the retromandibular vein (posterior facial vein) antero-inferior to the angle of the mandible.

Tributaries:

In the face:

(1) Veins from the ala nasi.
(2) Deep facial vein from the pterygoid venous plexus.
(3) Inferior palpebral vein.
(4) Superior and inferior labial veins.
(5) Buccinator vein.
(6) Parotid vein.
(7) Masseteric vein.

In the neck:

(8) Tonsillar.
(9) Submental.
(10) Ascending palatine.
(11) Submandibular.

Occasionally the venae comitantes of the hypoglossal nerve and the pharyngeal and the superior thyroid veins may open into the facial vein.

Communications:

(1) It communicates with the cavernous sinus by a vein which joins the supraorbital vein with the superior ophthalmic vein.

(2) It communicates with the cavernous sinus through the deep facial vein and pterygoid venous plexus. The deep facial vein connects the (anterior) facial vein with the pterygoid venous plexus which in turn communicates with the cavernous sinus by emissary veins which pass through foramen ovale, lacerum and emissary sphenoidal foramen, and by the inferior ophthalmic vein.

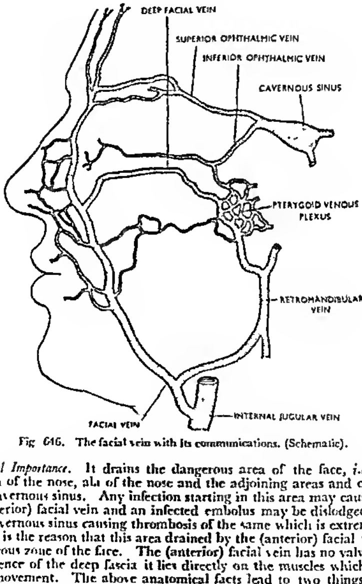

Fig 646. The facial vein with its communications. (Schematic).

Surgical Importance. It drains the dangerous area of the face, *i.e.*, the upper lip, septum of the nose, ala of the nose and the adjoining areas and communicates with the cavernous sinus. Any infection starting in this area may cause thrombosis of the (anterior) facial vein and an infected embolus may be dislodged and carried into the cavernous sinus causing thrombosis of the same which is extremely dangerous. This is the reason that this area drained by the (anterior) facial vein is called the dangerous zone of the face. The (anterior) facial vein has no valves and owing to the absence of the deep fascia it lies directly on the muscles which expose it to constant movement. The above anatomical facts lead to two things; it helps in the dislodgement of the clot and causes rapid spread of the infective process. Due to this rapidly spreading infection of the face, it may be necessary to put a ligature on the vein.

Deep facial vein. It comes from the pterygoid venous plexus and emerges on to the face between the anterior border of the masseter and the suctorial pad. It ends by opening into the (anterior) facial vein.

Lingual veins. The veins draining the tongue are dorsales linguae veins, profunda linguae vein and the venae comitans nervi hypoglossi.

Dorsales linguae veins drain the dorsum and the sides of the tongue and unite with the lingual veins accompanying the lingual artery and finally terminate into the internal jugular vein.

Profunda linguae vein drains the undersurface and the region of the tip of the tongue.

Venae comitans nervi hypoglossi. The profunda linguae vein joins with the sublingual vein to form the venae comitans nervi hypoglossi which accompany the hypoglossal nerve and after coursing backwards they end in the internal jugular vein.

Superior thyroid vein follows the superior thyroid artery and terminates into the internal jugular vein.

Middle thyroid vein drains the lower part of the thyroid gland and a part of the trachea and larynx and ends into the lower part of the internal jugular vein after crossing the common carotid artery.

THE EMISSARY VEINS

The emissary veins. The emissary veins are the smaller venules which pass through minute apertures on the cranium and establish communications between the cerebral sinuses and the veins outside the cranium.

Peculiarities. (1) Emissary veins are devoid of any valves; (2) blood can flow in both the directions; (3) the walls of these veins are formed only by the endothelium and there is no muscular coat.

Functions. Emissary veins being communicated to the cerebral sinuses, congestion of these sinuses can be relieved by applying leeches or counter-irritants over the site of an emissary vein. As blood can flow in both the directions, the intracranial equilibrium of venous pressure is maintained through these emissary veins.

Situation and number. The following emissary veins can be enumerated and their respective situations are given below:

1. *Emissary veins connected with the superior sagittal sinus:*

(*a*) An emissary vein passes through the foramen caecum of the frontal bone and connects the superior sagittal sinus with the veins of the nasal fossa or the (anterior) facial vein through a tributary which passes through the opening in the nasal bone.

(*b*) Parietal emissary veins, one on each side, pass through the parietal foramina and communicate it with the occipital vein.

2. *Emissary veins connected with the transverse sinus:* Sigmoid

(*a*) Two mastoid emissary veins, one on each side, pass through the mastoid foramina and connect the sigmoid part of the transverse sinus with the posterior auricular or the occipital vein.

(*b*) Two posterior condylar veins, one on each side, pass through the posterior condylar canals and connect the sigmoid or the lower ends of the transverse sinuses with the plexus of veins in the suboccipital triangles.

(*c*) Two anterior condylar emissary veins, one on each side, pass through the anterior condylar canals and connect the sigmoid part of the transverse sinus with the internal jugular vein.

(*d*) An emissary vein passing either through the post-glenoid foramen or through the squamosal foramen connects the external jugular vein with the transverse sinus via the petrosquamous sinus. This is not usually constant.

3. *Emissary veins connected with the cavernous sinuses:*

(*a*) An emissary vein passing through the foramen ovale connects the sinus with the pterygoid venous plexus.

(*b*) An emissary vein passing through the emissary sphenoidal foramen connects it with the pterygoid venous plexus.

(*c*) An emissary vein passing through the foramen lacerum connects it with the pterygoid venous plexus.

(*d*) A plexus of veins accompanying the internal carotid artery connects the cavernous sinus with the pharyngeal plexus of veins.

(*e*) The middle meningeal veins or sinuses, which pass through the foramen spinosum, sometimes behave like an emissary vein and connect the sinus with the pharyngeal plexus of veins.

(*f*) In a sense, the ophthalmic veins may be considered as emissary veins because blood can flow through them in an opposite direction that is, from the cranium to the orbit and along the tributaries which connect the ophthalmic vein with the (anterior) facial vein and along the channels which connect the ophthalmic vein through the inferior orbital fissure, with the veins of the infratemporal region.

N.B. Emissary veins are of great surgical importance. Inflammatory process starting outside the skull may spread into the cerebral sinuses through the emissary veins and thereby may lead to thrombosis of the same.

THE VEINS OF THE ORBIT

(*a*) *Superior ophthalmic vein.* It accompanies the ophthalmic artery and reaches the medial angle of the orbit where it communicates with the (anterior) facial vein.

(*b*) *Inferior ophthalmic vein.* It lies below the optic nerve and is joined with a vein which passes through the inferior orbital fissure to end in the pterygoid venous plexus.

The ophthalmic veins after receiving numerous tributaries pass backward through the gap between the two heads of the rectus lateralis and soon are joined together to form the cavernous sinus.

THE SINUSES OF THE DURA MATER

The sinuses of the dura mater may be conveniently grouped in the following ways:

(1) *Sinuses present in the median plane:*

(*a*) **Superior Sagittal Sinus.** It lies along the upper border of the falx cerebri and begins opposite the crista galli of the ethmoid bone where it sometimes receives a vein from the nose which passes through the foramen caecum of the frontal bone. It also receives the superior cerebral veins, veins from the pericranium, some meningeal veins and some venous lacunae from the dura mater. Opposite the internal occipital protuberance it ends either into the right or into the left transverse sinus (usually to the right).

There are three venous lacunae, frontal, parietal and occipital, which are nnected with each side of the superior sagittal sinus. They are irregular expan-ns of the superior sagittal sinus and are traversed by irregular fibrous strands ternally and into them the arachnoidal granulations protrude. Thus they form e chief drainage point for the return of the C. S. fluid into the blood of the superior

sagittal sinus. The posterior lacunae are larger and extend lateralwards for a variable extent. With age the number of the lacunae is reduced and usually at old age there is only one in connection with the superior sagittal sinus.

Applied Anatomy. In doing the trephine operation in the parietal region the position of the venous lacunae should be taken into consideration and in any case the medial edge of the trephine should be kept apart from the middle line by one inch in order to spare injury to the lacunae.

(*b*) **Inferior Sagittal Sinus.** It lies along the lower free concave margin of the falx cerebri. It is formed by the veins draining the falx cerebri and some of the veins draining the medial surface of the cerebral hemisphere. It ends into the straight sinus.

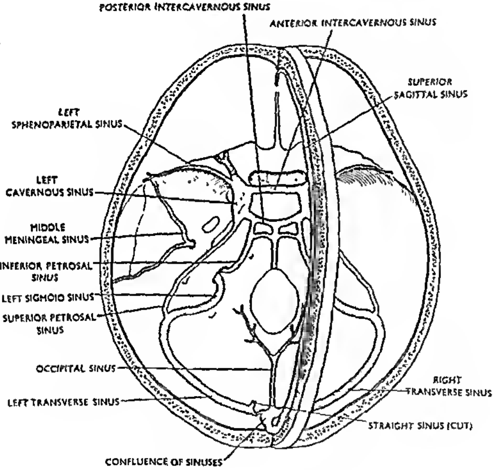

Fig. 647. The sinuses of the dura mater (Semi-diagrammatic).

(*c*) **Straight Sinus.** It lies along the line of attachment of the falx cerebri with the tentorium cerebelli. It begins as a direct continuation of the inferior sagittal sinus of the side opposite to that into which the superior sagittal sinus ends. It ends usually into the left transverse sinus. It is communicated to the confluence of sinuses by a small vein.

(*d*) **Occipital Sinus.** It lies in the upper part of the attached border of the falx cerebelli. It begins by the union of several small veins opposite the margins of the foramen magnum and ends into the confluence of sinuses.

2. *Sinuses present in the higher horizontal plane:*

Sphenoparietal Sinus. They are two in number, one on each side, and lie along the posterior border of the lesser wing of the sphenoid bone. Each begins by the union of the small venules draining the dura mater and ends into the cavernous sinus.

3. *Sinuses present in the lower horizontal plane:*

Cavernous Sinus. Each cavernous sinus is placed on the side of the body of the sphenoid bone and measures about 2 cm. in length and 1 cm. in breadth.

Formation, course and termination. Each is formed, at the medial end of the superior orbital fissure, by the union of the superior and inferior ophthalmic veins and then passes backwards to the apex of the petrous part of the temporal bone where it ends by dividing into superior and inferior petrosal sinuses.

Relations. Medially each cavernous sinus is related to the hypophysis cerebri and the sphenoidal air sinus; posteriorly it is related to the cavum trigeminale containing the semilunar ganglion of the trigeminal nerve. Laterally it is related to the temporal lobe of the brain in the region of the uncus.

In a section through the cavernous sinus, it is found to contain in its interior, the following structures:

(1) Internal carotid artery surrounded by the plexus of sympathetic nerves passes forwards close to the medial wall of the sinus.

(2) Abducent nerve lies on the infero-lateral aspect of the internal carotid artery.

(3) Lying on the lateral wall of the sinus in order from above downwards are the following nerves:

(*a*) Oculomotor, (*b*) Trochlear, (*c*) Ophthalmic and (*d*) the Maxillary nerves.

Communications:

(1) It communicates with the transverse sinus through the superior petrosal sinus.

(2) With the internal jugular vein through the inferior petrosal sinus.

(3) With the pterygoid venous plexuses through the emissary veins which pass through the foramen ovale, foramen lacerum, and emissary sphenoidal foramen (vesalii).

(4) With the (anterior) facial vein through the superior ophthalmic vein and through pterygoid venous plexus and deep facial vein.

(5) The two cavernous sinuses communicate with each other by the anterior and posterior intercavernous sinuses and the network of basilar sinuses.

(6) It communicates with the superior sagittal sinus through the superior anastomosing vein and the superficial middle cerebral veins.

(7) It communicates with the transverse sinus through the inferior anastomosing vein and the superficial middle cerebral veins.

Tributaries:

(1) Superior ophthalmic vein.
(2) A branch from the inferior ophthalmic vein.
(3) Superficial middle cerebral veins.
(4) Some inferior cerebral veins.
(5) Central vein of the retina.
(6) Anterior trunk of the middle meningeal sinus (sometimes).

Peculiarities. The peculiarity of the cavernous sinus is that its lumen is traversed by certain structures, as mentioned above, a feature which is not found in any other

veins in our body. These structures are separated from the blood by the lining membrane of the sinus. Instead of draining into a larger vein, as is usual with most of the veins, it ends by dividing into superior and inferior petrosal sinuses.

Its cavity, which is irregular in shape is interlaced by numerous fibrous strands which give it the appearance of the cavernous or spongy tissue and hence the sinus is well named as 'cavernous' sinus.

Development. The anterior part of the *primary head vein*, which lies medial to the trigeminal ganglion, forms the cavernous sinus.

The primary head-vein. The anterior cardinal veins which are the earliest intra-embryonic, paired longitudinal veins extending from the region of the eye to the sinus venosus, are divisible into cephalic nuchal and thoracic parts. The cephalic part of each anterior cardinal vein extends from the optic stalk to the medial aspect of the eleventh cranial nerve and then becomes continuous with its nuchal part. In its course it lies medial to the trigeminal ganglion, the otic vesicle, and the seventh to the eleventh cranial nerves. Subsequently, at a later date, the cephalic portion of the anterior cardinal vein that lies medial to the otic vesicle and the cranial nerves mentioned above disappears and is replaced by a *secondary new vein* which lies lateral to the otic vesicle and the cranial nerves. This new secondary vein follows the course of the facial nerve, becomes extracranial and terminates into the nuchal part of the internal jugular vein. *After the formation of this secondary venous channel the stem-vessel of the head is called the primary head-vein.*

Transverse sinuses. They are two in number, right and left, and run mostly transversely, hence the name "transverse sinus" and drain the blood from the superior and the inferior sagittal sinuses respectively to the corresponding sigmoid sinus.

The *right transverse sinus. Origin, course and termination.* It begins as a direct continuation of the superior sagittal sinus at a confluence, the confluence of sinuses (the bulbous dilatation at the point of meeting between the terminal end of the superior sagittal sinus and the commencement of the transverse sinus) at which the superior sagittal sinus takes a change in direction from the sagittal plane to the horizontal plane and is situated on the right side of the internal occipital protuberance.

It then runs horizontally lateralwards and forwards to lie in a groove successively on the squamous part of the occipital bone, mastoid angle of the parietal bone, mastoid portion of the temporal bone and the jugular process of the occipital bone. Then it comes out of the cranial cavity through the posterior compartment of the jugular foramen and becomes continuous with the internal jugular vein. In its course from the right side of the internal occipital protuberance to the mastoid process of the temporal bone it lies in between the two layers of the tentorium cerebelli and then it leaves the tentorium and is covered only by a fold of the meningeal layer of the dura mater. The S-shaped portion of the sinus that extends from the mastoid part of the temporal bone to the posterior compartment of the jugular foramen is known as the *sigmoid sinus*. Anteriorly the sigmoid part of the transverse sinus is separated from the tympanic antrum and the mastoid air cells by a thin plate of bone. The tentorial part of the transverse sinus is triangular on cross-section whereas the sigmoid sinus is semicircular on cross-section.

Tributaries:

Internal auditory veins—draining the internal ear.

Some veins draining the temporal lobe of the cerebrum, pons and the medulla oblongata.

Some of the superior and inferior cerebellar veins.

Temporal and occipital diploic veins.

Superior petrosal sinus—Just after its exit from the tentorium.

Occipital sinus at the confluence.

Petrosquamous sinus, when present.

Communications:

It communicates with the opposite transverse sinus.

It communicates with the posterior auricular or the occipital vein through the mastoid emissary vein passing through the mastoid emissary foramen.

It communicates with the vertebral veins by an emissary vein passing through the posterior condyloid foramen.

It communicates anteriorly with the external jugular vein by an emissary vein passing either through the post-glenoid or the squamosal foramen.

The left transverse sinus. It is smaller than the right transverse sinus and begins as a continuation of the straight sinus. It receives tributaries from the central ganglia of the cerebrum. Its course is similar to that on the right side.

Inferior petrosal sinuses. They are two in number, one on each side and each of sinuses begins at the bifurcation of the cavernous sinus and running obliquely downwards, backwards and laterally along the groove on the lateral aspect of the superior surface of the basilar part of the occipital bone, it reaches the anterior part of the jugular foramen. Then it comes out through the anterior compartment of the jugular foramen and after crossing the 9th, 10th and the 11th cranial nerves it ends into the internal jugular vein and *forms its first tributary.*

Two superior petrosal sinuses. One on each side, begin at the bifurcation of the cavernous sinus and running along the groove on the superior border of the petrous part of the temporal bone where it lies in between the two layers of the tentorium cerebelli it ends into the transverse sinus.

Sinuses running transversely and connecting the paired sinuses of opposite sides:

(*a*) **Anterior intercavernous sinus.** It lies at the anterior border of the diaphragm sellae and connects the two cavernous sinuses to each other anteriorly.

(*b*) **Posterior intercavernous sinus.** It lies at the posterior border of the diaphragm sellae and connects the posterior part of the two cavernous sinuses to each other.

(*c*) **Basilar plexus or sinus.** It lies on the basilar part of the occipital bone and connects the two inferior petrosal sinuses to each other.

The sinuses of the dura mater may also be grouped in the following ways:

(1) *Postero-superior group:*

(*a*) Superior sagittal
(*b*) Inferior sagittal
(*c*) Straight
(*d*) Two transverse
(*e*) Two sigmoid
(*f*) Occipital

(2) *Antero-inferior group:*

(*a*) Two cavernous
(*b*) Two sphenoparietal
(*c*) Two intercavernous
(*d*) Two superior petrosal
(*e*) Two inferior petrosal
(*f*) Basilar
(*g*) Middle meningeal.

THE VEINS OF THE BRAIN

The veins of the brain differ from other veins in that they are *devoid of any muscular wall,* they *have no valves* and they *do not accompany the cerebral arteries;* the veins opening either into the superior sagittal or into the transverse sinuses *drain their blood in a direction reverse to the direction of the current of the blood in the sinuses.* They have a fibrous wall which is lined by endothelium. They have an important bearing in that before reaching the sinuses of the dura mater, into which they open, they are to traverse the subarachnoid space and consequently are subjected to pressure of the cerebrospinal fluid. By opening into the venous stream against its current the venous flow in the cerebral veins is impeded thereby increasing their intraluminal pressure which is sufficient to counteract the pressure of the cerebrospinal fluid. Thus this arrangement prevents the cerebral veins from being collapsed during their passage through the subarachnoid space in which they are subjected to the pressure of the cerebrospinal fluid.

The cerebral veins are divided into *superficial or cortical* or *external* and *deep* or internal or *central group of veins*. The *superficial cerebral veins* come under the following heads: *superior*, *middle*, *inferior*, and the *anterior cerebral* and *basal veins*. The *deep group of veins* includes the *internal cerebral, thalamostriate, choroid, inferior striate, great cerebral*.

Superior cerebral veins. They are confined to the sulci on the superolateral and the medial surfaces of the cerebral hemisphere, although, some may run across the gyri, and consist of about 8 to 12 veins. They ascend upwards to the superomedial border of each cerebral hemisphere and finally end into the superior sagittal sinus. The anterior veins join the superior sagittal sinus at a right angle while the posterior ones join it at an acute angle being directed upwards and forwards (opens against the stream of the superior sagittal sinus).

Superficial middle cerebral vein. It is situated on the lateral surface of each cerebral hemisphere, drains this surface and follows the posterior ramus of the lateral sulcus to the basal aspect of the brain to reach the cavernous sinus into which it ends. Two anastomosing veins, superior and inferior, connect the superficial middle cerebral vein with the superior sagittal sinus and the transverse sinus respectively. Thus the superficial middle cerebral vein being a tributary of the cavernous sinus the latter is communicated to the superior sagittal sinus through the superficial middle cerebral vein and the superior anastomosing vein and with the transverse sinus through the superficial middle cerebral vein and the inferior anastomosing vein.

The *deep middle cerebral vein* lies in the bottom of the lateral. Sulcus and receives tributaries from the insula and the neighbouring gyri and terminates into the basal vein.

Inferior cerebral veins. These veins drain the inferior surface of each cerebral hemisphere. Those draining the orbital surface of the frontal lobe open into the superior cerebral vein and through it into the superior sagittal sinus. Those draining the inferior surface of the temporal lobe terminate into the superficial middle cerebral and into the basal vein.

The anterior cerebral vein follows the anterior cerebral artery, and ends into the basal vein; the *striate veins* drain the deeper structures of the cerebral hemisphere and come out through the anterior perforated substance.

Basal vein. It is formed by the union of the anterior cerebral, deep middle cerebral and the striate veins in the region of the anterior perforated substance. After its formation it runs backwards by the side of the cerebral peduncle and ends into the great cerebral vein.

The *cerebellar veins* are the superior and inferior cerebellar veins. The *superior cerebellar vein* opens into the great cerebral vein while the *inferior cerebellar veins* open into the occipital, sigmoid and inferior petrosal sinuses.

The choroid plexus and the deep cerebral veins. The choroid plexus is a highly vascular fringe of pia mater which secretes cerebrospinal fluid into the different ventricular cavities but that in the lateral ventricle is very much significant in which the bulk of the cerebrospinal fluid is secreted by it. The choroid plexus of the lateral ventricle is a highly vascular fringe of pia mater which projects into the ventricular cavity invaginating the ependymal medial wall of the ventricle and receiving from it a complete investment. It extends as far fowards as the interventricular foramen where it is continuous with the corresponding plexus of the opposite side. It consists of minute and highly vascular villous processes each possessing an efferent and afferent blood vessels. The *arteries of the plexus are the anterior choroid artery*, a branch of the internal carotid artery, which enters the plexus at the anterior end of the inferior horn of the lateral ventricle, and *one or two posterior choroid arteries*, branches of the posterior cerebral artery which enter into the plexus through the upper part of the choroidal fissure. The *veins of the plexus* unite to form a single tortuous vein, the *choroid vein*, which begins in the inferior horn of the ventricle and courses in the plexus to the interventricular foramen where they join with the corresponding *halamostriate* vein to form the corresponding *internal cerebral vein*. The two internal

cerebral veins run in of the tela chorioidea of the third ventricle and reaching below the splenium of the corpus callosum, where the two layers of the tela chorioidea separate from each other, they unite to form the *great cerebral vein* which curves backwards and upwards behind the splenium to join the straight sinus.

THE VEINS OF THE HEART

Coronary sinus. The coronary sinus is a part and partial of the heart being derived from the same source (sinus venosus) and forms its largest vein into which most of the veins draining the different parts of the heart open. It measures about one inch in length. It is completely buried within the muscular fibres of the heart and occupies the posterior part of the atrioventricular groove where it is situated in between the left ventricle and the left atrium. In the atrioventricular groove it passes slightly downwards to the right part of the same groove and opens into the lower part of the right atrium in between the inferior vena cava and the right atrioventricular orifice. At its opening it is guarded by a valve known as the *valve of the coronary sinus.*

Tributaries:

(*a*) Great cardiac vein.
(*b*) Small cardiac vein.
(*c*) Middle cardiac vein.
(*d*) Posterior vein of the left ventricle.
(*e*) Oblique vein of the left atrium.

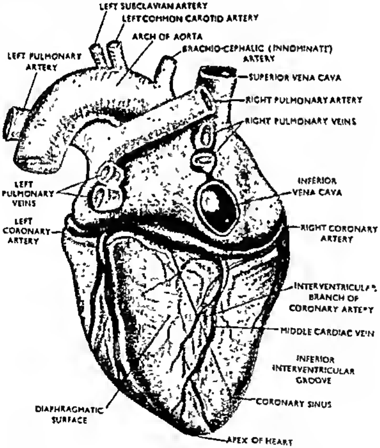

Fig. 648. The heart viewed from behind.
Note the position of the coronary sinus.
With the kind permission from Lederle Laboratories—drawn by Mr. Paul Peck.

N.B. Veins not opening into coronary sinus, drain themselves directly into the right atrium of the heart. They are (a) Anterior cardiac veins (b) Venae cordis minimae.

Development. The *coronary sinus develops from the left horn of the sinus venosus.*

With the formation of the transverse communication between the right and the left anterior cardinal veins most of the blood from the latter passes to the right side, and as a result, the left common cardinal (left duct of Cuvier) vein becomes such reduced in size; due to migration of the sinus venous to the right, the left common cardinal vein together with the proximal portion of the left anterior cardinal vein is pulled around the developing heart. Subsequently it (duct of Cuvier) is lodged in the atrioventricular groove and from its left horn the coronary sinus develops while the left duct of Cuvier forms the oblique vein of the left atrium.

The great cardiac vein. It lies in the anterior interventricular groove in company with the anterior interventricular branch of the left coronary artery and receives tributaries from the both the ventricles and the left atrium. Reaching the interval between the left auricle and the ascending aorta it takes a turn to the right to reach the left end of the posterior part of the atrioventricular groove where it becomes continuous with the coronary sinus.

The small cardiac vein. It receives tributaries from the right atrium and ventricle and winding the upper part of the right margin of the heart it reaches the atrioventricular groove where it ends by opening into the coronary sinus.

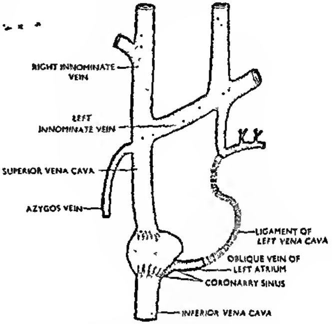

Fig. 649. The fate of the sinus venosus.
Note the development of the coronary sinus and the oblique vein of the left atrium.

The middle cardiac vein. It drains the diaphragmatic surface of both the right and left ventricles and lies in the inferior interventricular groove in company with the interventricular branch of the right coronary artery. It runs upwards and backwards to terminate into the coronary sinus.

The posterior vein of the left ventricle. It also drains the posterior part of the left ventricle and runs upwards to terminate into the coronary sinus.

The oblique vein of the left atrium. It drains the left atrium and descends obliquely downwards to terminate into the coronary sinus before it enters into the right atrium.

PULMONARY VEINS

The pulmonary veins are four in number, two on each side and they *carry oxygenated blood* from the lungs to the left atrium of the heart. The blood conveyed by the pulmonary veins *is not absolutely pure* because of the mixing into it of a small amount of blood from the pulmonary artery through the bronchial artery (*Vide* bronchial artery).

They begin in a capillary network around the walls of the lung-alveoli which is drained by smaller veins which unite together to form larger veins. From each lobule of the lung a single vein arises which joins with other lobular veins and ultimately lobular veins join together and a single vein comes out from each lobe of the lung at its hilum. Thus on the left side there are two pulmonary veins but those on the right side are three in number, one from each lobe of the lung. On the right side the vein from the middle lobe joins with the upper lobe vein to form a common trunk.

Course. From the hilum of the lung the pulmonary veins pass medially, pierce the pericardium and end by opening into the left atrium of the heart. While within the pericardium their anterior surfaces are covered by the serous pericardium.

Relations. At the hilum. The *superior pulmonary vein* lies in front of and a little below the pulmonary artery behind which there lies the main bronchus. The *inferior pulmonary vein* forms the lowest structure and is situated on a plane a little posterior to the plane of the superior pulmonary vein.

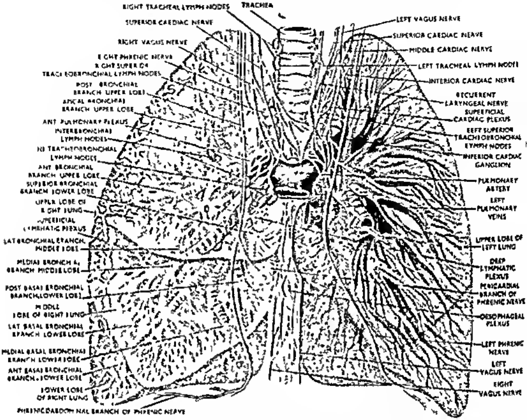

Fig 650. The Anatomy of the lungs (seen from the front.)
Note the dispositions of the pulmonary veins and the arteries.
With the kind permission from Lederle Laboratories—drawn by Mr. Paul Peck.

In the rest of the course. The superior right pulmonary vein, in its course to the heart, passes behind the superior vena cava while the inferior right pulmonary vein passes behind the right atrium of the heart. The left pulmonary veins in their course pass in front of the descending thoracic aorta. The oblique sinus of the pericardial cavity lies in between the four pulmonary veins.

Development. During early embryonic life the pulmonary veins originate as several vessels in connection with the various branches of the lung buds. They all converge to a *common single trunk* which enters into the left atrium dorsally. Thus at this stage, two large veins, one from the right and one from the left lung drain their contents into the left atrium of the heart. Later on, with the growth of the heart, the trunk vessels are gradually absorbed into the wall of the left atrium and consequently their tributaries, four in number, two from each lung, are found to be connected with the left atrium heart which condition is a feature of the adult form.

Anomalies. Occasionally a single pulmonary vein from any of the two lungs or from both the lungs may be found to open into the left atrium of the heart. This is due to the failure of the absorption of the trunk vessel mentioned above into the wall of the heart. Occasionally, on the right side, there may be three veins, instead

of two, to open into the left atrium. This is due to more extensive absorption of the trunk vessels including their remote tributaries. Occasionally, one of the pulmonary veins may be found to terminate either into the superior vena cava, left brachiocephalic or into the azygos vein. This anomalous condition may be explained by the fact that during the earliest part of the development of the blood vascular system, the developing lung bud, the foregut and the trachea are drained by vessels which are communicated to each other. Subsequently, with the change in vascular pattern, the connection of the pulmonary system of veins with the cardinal veins usually disappear but occasionally the above connection may persist giving rise to this type of anomaly.

THE SUPERIOR VENA CAVA

The superior vena cava. It drains blood from the head and neck, upper extremities, thorax and some portion of the abdomen to the right atrium of the heart.

Formation. The superior vena cava is formed by the union of the right and the left brachiocephalic (innominate) veins behind the right first costal cartilage close to the sternum.

Course and termination. From the level of the right first costal cartilage, it descends downwards behind the first intercostal space and reaching the level of the second costal cartilage it pierces the fibrous pericardium of the heart and opens into upper and posterior part of the right atrium of the heart at the level of the right third costal cartilage. The portion of the superior vena cava, which lies within the pericardium, constitutes the *intra-pericardial part* while that outside the pericardium, forms the *extra-pericardial part* of the superior vena cava. It measures about 7 c.m. in length and in its vertical course it maintains a curvature, the convexity of which is directed to the right side.

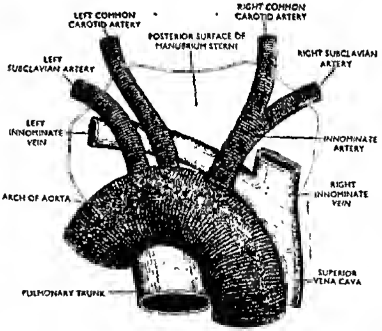

Fig. 651. The great vessels of the heart in relation to the manubrium sterni, seen from behind.

Relations. Above and anteriorly, it is covered by the anterior margin of the right lung and pleura. *Below and anteriorly* it is covered by the right lung pleura and the pericardium; the right lung and pleura above, and the right lung, right pleural sac and the pericardium below, separate the superior vena cava from the right internal thoracic artery, right second and the third costal cartilages and the right first and the second interocostal spaces. *Posteriorly*, it is related to the root of the right lung inferiorly whereas the right lung and the pleura lie postero-lateral to it above the root of the lung. The trachea and the right vagus nerve lie posteromedial to it.

On its *left side* is the ascending aorta and the brachiocephalic (innominate) artery, and on the *right side* it is related to the right phrenic nerve and the mediastinal pleura.

Tributaries:

(1) Right and left brachiocephalic (innominate) veins.
(2) Some pericardial veins.
(3) Some mediastinal veins.
(4) Azygos vein.

Development. The portion of the superior vena cava above the opening of the azygos vein is formed by the caudal end of the right anterior cardinal vein whereas the portion caudal to the opening of the azygos vein (intra-pericardial portion) is formed the persistent right duct of Cuvier.

Right brachiocephalic (innominate) vein. The right brachiocephalic vein is shorter than the left and is formed by the union of the right subclavian vein and the right internal jugular vein behind the sternal end of the clavicle. It is about one inch in length and it descends vertically downwards to the lower border of the cartilage of the first rib where it unites with the left brachiocephalic (innominate) vein to form the superior vena cava. It lies behind the sternal end of the clavicle and the cartilage of the first rib from which it is separated by the parietal pleura and the anterior margin of the right lung. *Postero-medially* it is related to the brachiocephalic (innominate) artery and the right vagus nerve. *Laterally and below* it is related to the right pleura and the right phrenic nerve. The right phrenic nerve and the right pleura lie posterior to it in its upper part.

It receives right internal jugular and right subclavian veins, the right vertebral, right internal thoracic (mammary) and right inferior thyroid veins, the first right posterior intercostal vein and the right lymphatic duct as its tributaries.

Left brachiocephalic (innominate) vein. It is much larger than the right brachiocephalic vein and measures about 6 cm. in length. It is formed by the union of the left subclavian and the left internal jugular veins behind the sternal end of the left clavicle and runs obliquely downwards and to the right to reach the sternal end of the right first costal cartilage where it joins with the right brachiocephalic (innominate) vein to form the superior vena cava. At its origin it is separated from the left sterno-clavicular articulation and the manubrium by the sternohyoid and the sternothyroid muscles and the remains of the thymus gland. In its course to the right it crosses the origins of the left subclavian, left common carotid and the brachiocephalic (innominate) arteries, the left phrenic and the left vagus nerves and the trachea. The arch of the aorta lies immediately below it.

Tributaries:

(1) Left internal jugular.
(2) Left subclavian.
(3) Left vertebral.
(4) Left inferior thyroid.
(5) Left internal thoracic (mammary).
(6) Left superior intercostal vein.
(7) Thoracic duct.

Azygos vein. *Origin.* The origin of the azygos vein is constantly variable. It may take its origin from the back of the inferior vena cava at or below the level of the right renal vein or it may be formed by the union of the right ascending lumbar vein and the right subcostal vein opposite the level of the twelfth thoracic vertebra. When it arises from the inferior vena cava it is called the *lumbar azygos vein*. The lumbar azygos vein is not always present while the trunk formed by the union of the right subcostal vein and the right ascending lumbar vein is constant. When the lumbar azygos vein exists, the venous trunk formed by the union of the right subcostal vein and the right ascending lumbar vein opens into it.

Course and relation. The lumbar azygos vein, when present, passes in front of the upper lumbar vertebrae and enters the thorax either by passing under cover of the right crus of the diaphragm or by piercing it or by passing through the aortic

opening in the diaphragm. Opposite the level of the twelfth thoracic vertebra it is joined by the tributary formed by the right ascending lumbar vein and the right subcostal vein. The further course of the azygos vein, whether it arises from the inferior vena cava or is formed by union of the right ascending lumbar vein and right subcostal vein, is the same in both the cases. It ascends through the posterior

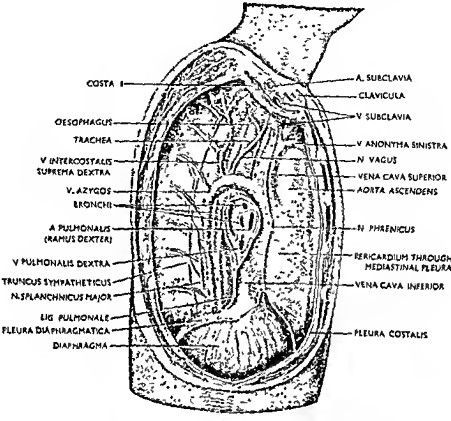

Fig. 652. The thoracic cavity seen from the right side. The lung has been removed. Note the *position of the azygos vein in relation to the root of the lung.*
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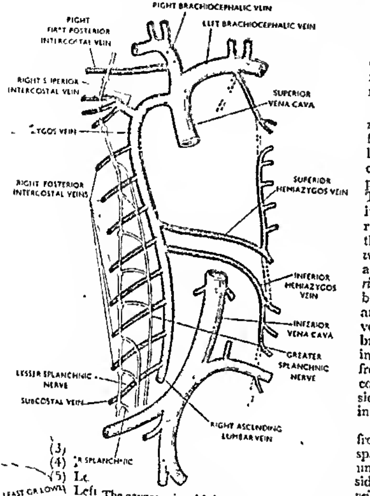
mediastinum in front of the lower eight thoracic vertebrae, anterior longitudinal ligament and the right aortic intercostal arteries. Reaching the level of the fourth thoracic vertebra it arches over the root of the right lung, and enters the superior mediastinum and finally ends by opening into the superior vena cava at the level of the second costal cartilage (*i.e.*, just before the superior vena cava pierces the fibrous pericardium). In its right side are the right lung and pleura and the greater splanchnic nerve. On its left side it is related to the thoracic duct and descending thoracic aorta throughout its course in the posterior mediastinum. The arch of the azygos vein, above the root of the right lung, is related to the oesophagus, trachea and the right vagus nerve on its left side. In the lower part of the posterior medastinum it is related, in front, with the oesophagus, and higher up, the hilum of the right lung forms its anterior relation.

Tributaries:

(1) Right posterior intercostal veins from the fourth to the eleventh spaces.
(2) Right superior intercostal vein.
(3) Superior and inferior hemiazygos veins.
(4) Oesophageal veins.

(5) Mediastinal veins.
(6) Pericardial veins.
(7) Bronchial veins.
(8) Venous channel formed by the right subcostal and right ascending lumbar veins (in case of lumbar azygos vein).

Development of the azygos vein. It is formed by the persistent cephalic part of the right posterior cardinal vein and by the persistent caudal part of the right supra-cardinal veins. The persistence of the posterior cardinal vein on the right side explains the origin of the azygos vein from the back of the inferior vena cava.



(3)
(4)
(5) Le
Left
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The azygos vein with its tributaries.

Fig. 653.

Posterior intercostal veins. The vein from the first intercostal space on both sides, opens into the corresponding brachiocephalic (innominate) vein. The second and the third intercostal veins on the right side unite to form the *right superior intercostal vein* which opens into the azygos vein. The *left superior intercostal vein* formed by the union of the second and the third intercostal veins opens into the left brachiocephalic (innominate) vein. The veins from the lower eight intercostal spaces on the right side open independently into the azygos vein.

The intercostal veins from fourth to eighth spaces on the left side unite to form, on the left side, the *superior hemiazygos vein* whereas the veins from the remaining interspaces form the *inferior hemiazygos* vein. Both the superior and the inferior hemiazygos veins open into the azygos vein.

THE SUPERFICIAL VEINS OF THE UPPER EXTREMITY

The superficial veins of the upper limb commence in the superficial fascia of the palm and dorsum of the hand and the digits and they may be grouped as the veins of the digits and hand and the veins of the forearm and the arm.

The veins of the digits and the hand. On the dorsum of the digits, the superficial veins begin as the *dorsal digital veins* which are two in number in each digit and communicate freely with each other on the dorsum of the digit. Each dorsal digital vein, opposite the distal end of the intermetacarpal space, is reinforced by the inter-

capitular veins which are draining blood from the venous network on the palm of the hand and passing in between the heads of the metacarpal bones join the dorsal digital vein. The dorsal digital veins from the contiguous sides of the index and middle fingers, middle and ring fingers and the ring and the little fingers, unite together opposite the distal end of the corresponding intermetacarpal space to form the three *dorsal metacarpal veins*. On the dorsum of the hand these three dorsal metacarpal veins are connected to each other and also joined by the dorsal digital vein from the ulnar side of the little finger and from both the sides of the thumb and from the radial side of the index finger to complete the formation of the *dorsal venous network*. From the radial side of this venous network the cephalic vein arises and from its ulnar side the basilic vein arises.

The superficial veins of the volar aspect of the digits form the volar digital veins which communicate proximally with the venous network on the superficial fascia of the palm of the hand. At the distal end of each intermetacarpal space, each palmar digital vein is joined with the dorsal digital vein by the intercapitular vein. From the palmar venous network the median vein of the forearm arises.

Veins of the forearm and arm. The superficial veins of the forearm are the cephalic, basilic, the median cubital vein, which connects the cephalic and basilic veins together, and the median vein of the forearm.

Cephalic vein. It arises from the radial side of the dorsal venous network and receives the dorsal digital veins from the radial side of the index finger and from both the sides of the thumb. At its origin it crosses superficially the radial artery and the digital branches of the radial nerve opposite the anatomical snuff-box. Then it turns round the radial margin of the lower part of the forearm and ascends upwards on the volar aspect of the forearm in parallel to the volar margin of the brachioradialis muscle to the front of the elbow joint. Here it is connected with the basilic vein by the median cubital vein. Then it crosses superficial to the lateral cutaneous nerve of the forearm and lies in the groove between the brachioradialis and the biceps brachii and then ascends upwards along the lateral border of the biceps muscle to reach the intermuscular furrow between the deltoid and the pectoralis major muscle. Accompanied by the deltoid branch of the acromio-thoracic artery it reaches the delto-pectoral triangle and then it turns medially between the pectoralis minor and the pectoralis major to the anterior aspect of the clavipectoral fascia, which separates it from the anterior aspect of the

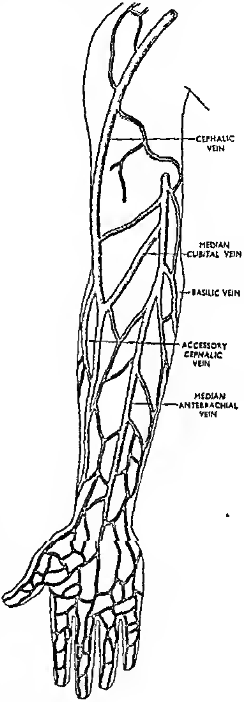


Fig. 654. The superficial veins of the upper extremity. Seen from the front.

first of the axillary artery. Finally it turns backwards and pierces the clavipectoral fascia and ends in the axillary vein.

N.B. In some cases cephalic vein does n pierce the clavipectoral fascia but it ascends u wards over the clavicle and then piercing the dee cervical fascia it ends in the internal jugular vei Sometimes the cephalic vein is much reduced in si and the median cubital vein becomes very pr minent and the bulk of the blood passes from it t the basilic vein.

Basilic vein. It begins from th ulnar side of the dorsal venous networl and receives the dorsal digital vein fron the ulnar side of the little finger. Then it ascends upwards along the posterio part of the ulnar side of the forearm anc a little below the elbow joint it incline forwards to reach the volar aspects of the forearm. Then it passes upwards in fron of the ulnar side of the front of the elbow joint and lies in the groove between the pronator teres and the biceps, where it is joined by the median cubital vein Reaching a little below the middle of the arm it pierces the deep fascia and ascends upwards along the medial side of the brachial artery to the lower border of the teres major muscle, where it is continued upwards as the axillary vein.

Median cubital vein. It is a short oblique vein placed in front of the bend of the elbow joint and connecting th cephalic and the basilic veins together. It crosses obliquely in front of the terminal part of the brachial artery but being separated from it by the bicipital aponeurosis; it receives some deep veins of the forearm.

Median vein of the forearm. It begins from the palmar venous network and ascends upwards opposite the middle of the forearm and a little below the bend of the elbow joint it divides into two branches, the median basilic and median cephalic veins. The median basilic connects it with the basilic vein while the median cephalic connects it with the cephalic vein. When the median vein of the forearm is present the median cubital vein is usually wanting.

N.B. The median cubital vein being more or less fixed, it is the choice to perform venesection in this vein.

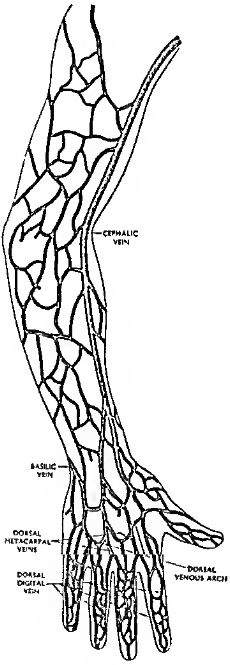


Fig. 655. The superficial veins of the upper limb. Seen from the behind.

DEEP VEINS OF SUPERIOR EXTREMITY

The deep veins of the superior extremity are comparatively smaller because most of the blood drains through the superficial veins. They accompany the arteries as their venae comitantes being arranged in pairs, one on each side of the arteries.

In their course they are cross-connected to each other by transverse veins which pass across the arteries. They are also communicated to the superficial veins.

In the hand the deep veins begin as venae comitantes of the superficial and the deep palmar arches (arteria) and form the *superficial* and the *deep venous arches respectively*. The *superficial venous arch* is formed by the union of the palmar digital veins whereas the *deep venous arch* is formed by the union of the palmar metacarpal veins and with the veins corresponding to the branches of the respective arterial arch.

In the forearm the deep veins are the venae comitantes of the ulnar and the radial arteries. The venae comitantes for the ulnar artery are formed by the direct continuation of the veins that drain the superficial palmar venous arch while those for the radial artery are formed by the veins draining the deep palmar venous arch. They ascend upwards along with the ulnar and the radial arteries and reaching the cubital fossa they are united to form the *brachial veins.* At the elbow the ulnar venae comitantes receive the anterior and the posterior interosseous veins and are communicated to the median cubital vein.

The brachial veins or the venae comitantes for the brachial artery follow the latter and end by draining into the axillary vein at the lower border of the subscapularis muscle. Their tributaries correspond with the branches of the brachial artery.

The **axillary vein** begins as a direct continuation of the basilic vein opposite the lower border of the teres major and ascends upwards through the axilla to the outer border of the first rib where it ends by being continuous with the subclavian vein. It lies on the medial side of the axillary artery, and the medial pectoral nerve, the medial cord of the brachial plexus, the medial antibrachial cutaneous nerve and the ulnar nerve intervene between the artery and the vein.

The tributaries of the axillary vein are the cephalic vein, brachial veins and the veins that accompany the branches of the axillary artery. The cephalic vein opens into it close to its termination.

The **subclavian vein** begins as a direct continuation of the axillary vein from the level of the outer border of the first rib and running upwards and medially it unites with the internal jugular vein at the medial border of the scalenus anterior muscle to form the brachiocephalic (innominate) vein. Anteriorly it is related to the clavicle and the subclavius muscle; posteriorly it is separated from the subclavian artery by the scalenus anterior muscle on the left side and, on the right side, the right phrenic nerve intervenes between them. Inferiorly it rests upon the first rib and upon the pleura over the apex of the lungs.

The tributaries of the subclavian are external jugular and some small veins from the infraclavicular regions which ascend over the clavicle. It occasionally receives the anterior jugular vein and a tributary from the cephalic vein. The thoracic duct opens in the angle of junction between the left subclavian and the left internal jugular vein whereas the right lymphatic duct opens into it in the corresponding angle on the right side.

THE INFERIOR VENA CAVA AND ITS FAMILIES

Inferior vena cava. *course.* The inferior vena cava is formed by the union of the two common iliac veins opposite the level of the fifth lumbar vertebra a little to the right of the median plane. It runs upwards in front of the lumbar vertebrae lying on the right side of the abdominal aorta. Then it enters a groove on the posterior aspect of the right lobe of the liver and passes through the vena caval opening in the diaphragm and finally pierces the fibrous pericardium to end into the lower and posterior part of the right atrium of the heart. At its termination it is guarded by a rudimentary valve known as the *valve of the inferior vena cava.*

Relations:

Anteriorly: (From above downwards)
Liver,
Aditus to the lesser sac,
Portal vein,
Head of the pancreas,
Third part of the duodenum,
Right testicular or ovarian vessels,
Superior mesenteric artery,
The mesentery,
Commencement of the right common iliac artery.

Posteriorly:
Bodies of the lumbar vertebrae,
Anterior longitudinal ligament,
Right psoas major muscle,
Right sympathetic trunk,
Right crus of the diaphragm, righ renal, right suprarenal, right phreni and right lumbar arteries, right supra renal gland.

On the left side:
Abdominal aorta, right crus of th diaphragm, caudate lobe of the liver

On the right side:
Right ureter,
Medial aspect of the posterior surfac of the second portion of the duodenum right lobe of liver and the hilum o right kidney.

Tributaries:

(1) Renal.
(2) Hepatic.
(3) Right suprarenal.
(4) Right phrenic vein.
(5) Right testicular or ovarian vein.
(6) Lumbar veins (third and fourth).
(7) Common iliac veins.

Serous relations. Above the first part and below the third part of the duodenum it is covered in front by the parietal peritoneum. In the thorax within the pericardium it is covered in front and at the sides by the serous pericardium.

Development of the inferior vena cava. From below upwards the inferior vena cava is developed from the following primitive veins.

The persistent post-renal part of the right supracardinal vein joins with the right subcardinal vein by a transverse connection and then it is continued upwards as the persistent prerenal part of the right subcardinal vein. Beyond the level of the renal vein the right subcardinal vein disappears and another vein extends upwards from the upper end of the persistent right subcardinal vein to the liver where it joins the hepatic veins and finally its prehepatic part is formed by the persistent right vitelline vein which opens into the right atrium of the heart.

Anomalies. *Anomaly of formation.* The inferior vena cava may be formed at a higher level opposite the second lumbar vertebra; in such cases the two common iliac veins ascend upwards, one on each side of the abdominal aorta; the left common iliac vein near its termination receives the left renal vein and then passes either in front of or behind the abdominal aorta to gain its right side where it joins with the right common iliac vein.

Anomaly of termination. Instead of opening directly into the right atrium it may terminate into the azygos

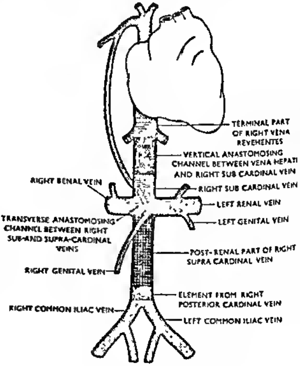


Fig. 656. The development of the inferior vena cava.

vein. In such cases the hepatic veins terminate into the right atrium of the heart by a common venous channel (Vena revehentes). Occasionally it is placed on the left side of the abdominal aorta; the left sided inferior vena cava may pierce through the left crus of the diaphragm to enter into the thorax where it replaces the inferior hemiazygos vein and then crossing the median plane like the hemiazygos vein terminates into the azygos vein; in such cases it ascends still further, arches over the root of the left lung and then passing behind the left atrium it terminates into the right atrium on the situation of the coronary sinus.

Anomaly of Course. As mentioned above it may take its course upwards on the left side of the abdominal aorta and may terminate as mentioned above; it may, however, cross to the left side opposite the level of the first or second lumbar vertebra and then takes its usual course.

Anomaly of tributaries. The hepatic veins may not terminate into it and instead, they may open separately or by a common stem into the right atrium of the heart. Lumbar veins of one or the both sides may form a common stem to open into it. There may be additional testicular or ovarian, renal or suprarenal veins.

Hepatic veins. The hepatic veins form the efferent vessels of the liver and collect the blood from its afferent vessels (portal vein and hepatic artery). They begin as *intralobular* or central veins within the centre of each hepatic lobule and the central veins from the different lobules unite together to form inter- or sublobular veins; the sublobular veins unite together to form three larger veins, the hepatic veins, right, left and middle, which open into the inferior vena cava on the posterior surface of the liver.

Right suprarenal vein. It emerges from the hilum of the right suprarenal gland and runs upwards for a short course to terminate into the back of the inferior vena cava (The left suprarenal vein opens into the left renal vein).

Right phrenic vein. It corresponds to the phrenic arteries and is formed by smaller tributaries draining the diaphragm. The phrenic vein on the right side ends into the upper part of the inferior vena cava. The left phrenic vein opens into the left suprarenal vein or into the left renal vein.

Right testicular vein. The testicular veins begin as a plexiform network of veins, the *pampiniform plexus*, which emerges from the testis and the epididymis. The plexus consists of eight to ten veins which ascend upwards in front of the vas deferens to the superficial inguinal ring where they unite to form two veins which traverse through the inguinal canal and reaching the deep inguinal ring they unite to form a single vein. The latter enters into the abdomen through the deep inguinal ring and then follows the testicular artery and finally ends into the inferior vena cava. The left testicular vein terminates into left renal vein.

The **right ovarian vein** begins in the same way as the testicular veins. The smaller veins which emerge from the hilum of the ovary are united together to form the *pampiniform plexus* which lies between the two layers of the broad ligament and extends as far as the pelvic brim. Two veins emerge from the plexus which soon unite to form a single vein which on the right side ends into the inferior vena cava. The left ovarian vein terminates into the left renal vein.

Lumbar veins. There are altogether five lumbar veins on each side, the upper four amongst which, accompany the corresponding lumbar arteries while the lowest one follows the lumbar branch of the median sacral artery. The upper two lumbar veins terminate either into the corresponding ascending lumbar vein or into azygos or hemiazygos veins. The third and the fourth lumbar veins usually terminate into the inferior vena cava while the fifth one terminates into the ilio-lumbar vein.

Renal veins. The renal veins are two in number, right and left, and each drains the corresponding kidney. They lie in front of the renal artery and the pelvis of the ureter lies below and behind the vein. The right renal vein is about one inch in length while the left is three times longer than the right and measures about 3 inches.

Right renal vein. It is about one inch in length and by passing behind the second part of the duodenum and the head of the pancreas it ends in the inferior vena cava opposite the level of the second lumbar vertebra.

Left renal vein. The left renal vein is the common vein for the three glands on the left side viz., the left suprarenal gland and the left testis or ovary and the left kidney and it is about three times longer than the right because it has to cross the vertebral column before it reaches the inferior vena cava. Developmentally it is the upper cross-communication between the right and the left subcardinal and the left posterior cardinal veins.

It begins in the hilum of the left kidney by the union of two or three smaller veins opposite the level of the first lumbar vertebra and lies at first in front of the left renal artery. Then it crosses in front of the left psoas major, left crus of the diaphragm and the abdominal aorta and ends by opening into the inferior vena cava at a right angle opposite the level of the second lumbar vertebra and a little above the level of the right renal vein. Anteriorly, from left to the right, it lies under cover of the body of the pancreas together with the splenic vessels, superior mesenteric vessels and the head of the pancreas.

Tributaries of the left renal vein: (1) Left testicular or ovarian vein opens into its lower border at a right angle about one inch from the hilum of the kidney. (2) Left suprarenal vein, it receives the left inferior phrenic vein before it opens into its upper border.

Development of the left renal vein. The left renal vein at first opens into the posterior cardinal vein of the left side. A transverse vein later on joins the two subcardinal veins to each other opposite the level of the renal vein and also extends sidewards to communicate with the posterior cardinal veins. After sometime the subcardinal vein of the left side disappears except for a small extent cranial to the transverse vein. The posterior cardinal vein of the left side disappears both above and below the level of the renal vein. Thus the left renal vein is formed by the left posterior cardinal, left subcardinal and by the transverse vein that connects the two subcardinal and the left posterior cardinal veins together.

N B—The incidence of varicocele of the left testicular vein is higher than the right. Several different views have been put forward to reason it out; (1) that the left suprarenal vein which opens into the left renal vein pours out the adrenalin-ladden blood into the left renal vein which affects its calibre resulting in congestion of the left testicular vein; (2) that the valvular arrangement is imperfect in the left testicular vein which affects proper drainage of the blood and causes congestion in the left testicular vein; (3) that the left renal vein is clasped between the superior mesenteric artery and the abdominal aorta, thereby causing obstruction in the flow of blood which results in congestion of blood in the left testicular vein, (4) that the left testicular vein being longer than the right it has to hold a longer column of blood which affects adversely in the efficient drainage of the vein; (5) that the left testicular vein opens at a right angle to the left renal vein which causes hindrance to the flow of blood. In my opinion mechanical obstruction by the superior mesenteric artery is a reasonable cause to this condition because cases have been recorded where even the third part of the duodenum had been seen to be compressed by the superior mesenteric artery.

Ascending lumbar vein. It is a longitudinal venous channel placed deeply in front of the transverse processes of the lumbar vertebrae and behind the psoas major muscle; in its course upwards it connects the common iliac, ilio-lumbar and the lumbar veins together and then ascends in front of the twelfth thoracic vertebra and is then continued as the azygos vein on the right side and as the inferior hemiazygos vein on the left side. The ascending lumbar vein is joined by a small vein which connects it with the inferior vena cava and this small vein which connects the inferior vena cava with the ascending lumbar vein is known as the *lumbar azygos vein*.

Common iliac veins. The common iliac veins are two in number, right and left, which unite together on the right side of the body of the fifth lumbar vertebra at an acute angle to form the inferior vena cava. Each common iliac vein is formed by the union of the external and internal iliac veins in front of the sacro-iliac articulation. The *right common iliac vein* is shorter than the left and is vertical in direction. It lies at first to the right of the common iliac artery and then posterior to it. The *left common iliac vein* is longer and oblique in direction. It is crossed by the inferior mesenteric vessels and root of the pelvic mesocolon. It at first lies medial to the left common iliac artery and finally ends behind the right common iliac artery.

Tributaries:

(1) External iliac vein.
(2) Internal iliac vein.
(3) Ilio lumbar.
(4) Lateral sacral.

The left common iliac vein receives in addition the median sacral vein.

External iliac vein. It begins at the level of the inguinal ligament as a continuation of the femoral vein and at its origin it lies behind the inguinal ligament and medial to the distal end of the external iliac artery. It runs upwards along the brim of the pelvis and lies at first medial, then postero-medial and finally posterior to the external iliac artery. Opposite the sacro-iliac articulation it unites with the internal iliac vein to form the common iliac vein.

Tributaries:

(1) Deep circumflex iliac.
(2) Inferior epigastric.
(3) Pubic veins (occasionally).

Deep circumflex iliac vein. It is formed by the union of the venae comitantes that accompany the deep circumflex iliac artery and after crossing the external iliac artery it ends into the external iliac vein about half an inch above the inguinal ligament.

Inferior epigastric vein. It is also formed by the union of the venae comitantes of the inferior epigastric artery and terminates into the external iliac vein about half an inch above the inguinal ligament. It communicates above with the superior epigastric vein.

Pubic vein. It arises from the obturator vein in the obturator canal and ascends upwards on the pelvic surface of the pubis along with the pubic branch of the inferior epigastric artery and finally ends into the external iliac vein. Thus it appears that the pubic vein is mainly a communicating vein between the external iliac and the obturator veins. Occasionally it becomes very much enlarged to replace the obturator vein.

Internal iliac vein. It is a short venous channel which is formed near the upper margin of the greater sciatic foramen by the union of tributaries which correspond to the branches of the internal iliac artery except its umbilical and iliolumbar branches. After its formation it ascends on the medial side of the internal iliac artery to reach the pelvic brim where it ends by joining with the external iliac vein to form the common iliac vein.

Tributaries:

The tributaries of the internal iliac vein may conveniently be divided into parietal and visceral groups. The parietal group of tributaries consists of extra-pelvic and intra-pelvic sets which follow the corresponding branches of the internal iliac artery. Thus the tributaries are summarised as below:

Parietal group:

Extra-pelvic set

(1) Superior gluteal.
(2) Inferior gluteal.
(3) Obturator.
(4) Internal pudendal.

Intra-pelvic set:

Lateral sacral.

Visceral. The visceral tributaries of the internal iliac vein are arranged in plexiform networks around the different viscera contained in the pelvic cavity namely, the urinary bladder, prostate and the rectum in the male, and the urinary bladder, uterus, vagina and the rectum, in the female. The visceral venous plexuses are formed by thin-walled veins and they freely communicate with one another. The

visceral venous plexuses are collectively called the *pelvic venous plexus* which consist of the following:

(1) Vesical venous plexus.
(2) Prostatic venous plexus. } in the male.
(3) Rectal venous plexus.

(4) Vesical venous plexus.
(5) Uterine plexus. } in the female.
(6) Vaginal plexus.

Vesical venous plexus in the male. It lies on the external aspect of the musculature of the urinary bladder and forms a dense network, particularly in the region of the neck where it surrounds the seminal vesicles, terminal part of the vas deferens and the ureter. The vesical venous plexus communicates in front with the prostatic venous plexus and is drained by a few small veins which open into the internal iliac vein.

Vesical venous plexus in the female. Here the place of prostatic venous plexus in the male is represented by a part of the vesical venous plexus that surrounds the upper part of the urethra. The vesical venous plexus in the female communicates in front with the vaginal venous plexus and receives the deep dorsal vein of the clitoris.

Prostatic venous plexus. It is placed between the true and the false capsules of the prostate. It receives in front the deep dorsal vein of the penis and communicates behind with the vesical venous plexus. It is drained by a few veins which open into the internal iliac veins.

Uterine venous plexus. It lies on both sides of the uterus between the two layers of the broad ligament and is drained by a pair of uterine veins, one on each side, which opens into the internal iliac veins. The tributaries of this plexus which drain the uterus have no valves. It communicates in front with the vaginal plexus, and behind, with the ovarian plexus.

Vaginal venous plexus. It lies on each side of the vagina and drains the walls of the vagina. The plexus on each side is drained by the vaginal vein which terminates into the internal iliac vein. Each plexus communicates above with the uterine plexus, below with the veins from the bulb of the vagina, in front with the vesical plexus and behind with the rectal plexus.

Rectal venous plexus. It surrounds the rectum and consists of an *external plexus* lying outside the muscular wall and an *internal plexus* lying in the submucous coat. The internal venous plexus is arranged in vertical columns which begin just above the anal orifice and are connected to each by transverse veins. It is drained by the superior rectal vein—although it freely communicates with the external plexus. The lower part of the external venous plexus is drained by the inferior rectal vein which opens into the internal pudendal (systemic) vein; its middle part by the middle rectal vein which drains into the internal iliac vein (systemic vein) whereas its upper part is drained by the superior rectal vein (portal system of vein).

Dorsal veins of the penis and clitoris. The dorsal veins of the penis consists of two veins, *superficial dorsal vein* and *deep dorsal vein.* The *superficial dorsal vein drains* the prepuce and the skin of the penis and lies in the sub-cutaneous tissue. It drains into the external pudendal vein of either the right or the left side which is a tributary of the long saphenous vein. The *deep dorsal vein lies deep to the fascia of the penis in the median plane between the two dorsal arteries.* It drains the glans penis and the corpora cavernosa penis and passes upwards to the root of the penis where it lies between the two limbs of the suspensory ligament; then it turns downwards and backwards to enter the gap between the inferior pubic ligament and the anterior margin of the perineal membrane. Here it divides into the branches which communicate with the internal pudendal vein and terminate into the prostatic venous plexus.

The deep *dorsal vein of the clitoris* in the female has a similar course and it terminates in the similar way into the vesical venous plexus.

Superior gluteal veins. They accompany the superior gluteal artery as its venae comitantes and drain the muscles in the gluteal region. They enter the pelvic cavity through greater sciatic foramen and unite to form a single vein which ends into the internal iliac vein.

Inferior gluteal veins. They begin in the subcutaneous tissue in the region of the back and ascends upwards as venae comitantes of the inferior gluteal artery. In the gluteal region they are situated deep to the gluteus maximum muscle and receive tributaries from the muscles in this region. They enter the pelvic cavity through the greater sciatic foramen and unite to form a single vein which terminates into the internal iliac vein.

Obturator vein. It is formed in the region of the thigh by tributaries from the muscles of the upper and medial parts of the thigh and from the hip joint. It enters into the pelvic cavity through the obturator canal and accompany the obturator artery being placed above it. It finally ends into the internal iliac vein.

Internal pudendal veins. They accompany the internal pudendal artery as its venae comitantes and communicate with the prostatic venous plexus (in the male) at the root of the penis. They drain the corpus cavernosa penis through the deep vein of the penis, clitoris, perineal muscles, the lower part of the rectum and the anal canal through inferior rectal vein and the muscles of the gluteal region. They unite to form a single vein which ends into the internal iliac vein.

Lateral sacral veins. They accompany the lateral sacral arteries and terminate into the internal iliac vein. They communicate with the *anterior sacral venous plexus*.

Median sacral veins. They form the venae comitantes of the median sacral artery and near the brim of the pelvis they unite to form a single vein which terminates into the left common iliac vein.

Iliolumbar vein. It receives tributaries from the vertebral canal, lower part of vertebral muscles, and from the muscles and other tissues of the iliac fossa. It follows the corresponding artery in the abdomen only and does not enter into the pelvic cavity. From the region of the iliac fossa it passes deep to the psoas major muscle and finally ends into the posterior part of the common iliac vein.

THE PORTÁL SYSTEM OF VEINS

The portal vein. It is the principal afferent vessel of the (venous channel) liver which drains the whole of the gastro-intestinal tract from the stomach down to the anal canal except its extreme lower part, the gall bladder, the spleen and the pancreas and conveys the blood to the liver. From the liver the blood is drained to the inferior vena cava through the hepatic veins (Efferent vessels of the liver). It is a peculiar vein in that it begins as a vein but it ends like an artery by dividing into branches. It carries deoxygenated blood *but contains the products of digestion as well.* It has no valves internally and its muscular wall is well developed.

For descriptive purposes the portal vein may be divided into two parts, extra-hepatic part and intra-hepatic part.

Extra-hepatic part: *Formation.* It is formed by the union of the superior mesenteric vein and the splenic vein, opposite the body of the second lumbar vertebra, in front of the inferior vena cava and behind the neck of the pancreas.

Length and course. The portal vein is about three inches long and after its formation it runs upwards and to the right behind the superior (first part) part of the duodenum. Then it reaches the right free border of the lesser omentum where it forms the anterior boundary of the aditus to the lesser sac and finally reaches the right end of the porta hepatis.

Termination. At the right end of the porta hepatis it terminates by dividing into a short and stout, right branch, and a long, narrow left branch. The *right branch* receives cystic vein and then enters into the right lobe of the liver. The *left branch* passes from the right to the left in the porta hepatis and reaches the fissure for the ligamentum teres and finally it crosses the fissure and ends by entering into the left lobe. In its course through the porta hepatis, the left branch of the portal vein gives branches to the caudate and the quadrate lobes of the liver.

Relations. At its origin the portal vein is related, *in front*, to the neck of the pancreas, *behind*, to the front of the inferior vena cava. Behind the superior (first part) part of the duodenum it lies in front of the inferior vena cava and behind the common bile duct and the gastroduodenal artery which lies on the left side of the common bile duct. In the lesser omentum it is contained between its two layers opposite its right free margin; the hepatic artery and the common bile duct both lie in front of it, the duct being placed on the right side of the artery; in this situation it is separated from the inferior vena cava by the aditus to the lesser sac. In the porta hepatis it forms the posterior most structure; the hepatic ducts lie anteriorly and intervening between them and the branches of the portal vein are the hepatic arteries.

Intra-hepatic part. Within the liver each branch of the portal vein divides into numerous branches and ultimately forms the interlobular vein which joins with a similar branch from the hepatic artery to form the *hepatic sinusoid.* Each sinusoid passes towards the centre of each lobule and ends by draining into the *central vein* which ultimately drains into the hepatic veins.

Vestigial structures in connection with the portal vein. The left branch of the portal vein, as it crosses the fissure for the ligamentum teres, is connected in front with the ligamentum teres, a fibrous cord, and behind, with another fibrous cord, the ligamentum venosum. The ligamentum teres is the fibrous remnant of the foetal left umbilical vein whereas the ligamentum venosum is the fibrous remnant of a foetal vein, the *ductus venosus,* through which, during foetal life, most of the blood from the placenta is bypassed the liver into the inferior vena cava.

Tributaries:

(1) Splenic.
(2) Superior mesenteric.
(3) Right gastric.
(4) Left gastric.
(5) Cystic.
(6) Para-umbilical.

Communications with the systemic veins:

(1) *Opposite the lower end of the oesophagus.* The *left gastric vein* which drains into the portal vein, communicates with the *oesophageal veins* which are systemic veins and open into the inferior vana cava and the azygos vein.

(2) *At the lower end of the rectum.* *The superior rectal vein* which is a tributary of the portal system of veins (opening into splenic vein), communicates freely with the *inferior and middle rectal veins* at the lower end of the rectum. The middle rectal vein directly opens into the internal iliac vein while the inferior rectal vein opens into the internal iliac vein through the internal pudendal vein (systemic veins).

(3) *Behind the colon.* In front of the kidney the *renal vein* (systemic) communicates with the veins of the colon and peritoneum (portal) through some small veins.

(4) *At the bare area of the liver.* Some veins connect the *diaphragmatic veins* (systemic) with the *veins of the liver* (portal).

(5) *Within the liver.* Branches of the *portal vein* communicate freely with the *hepatic veins* (systemic).

(6) *Around the umbilicus.* Paraumbilical vein (portal) communicates with the tributaries of the epigastric veins (systemic).

Development.—The portal vein is developed from the persisting portions of the right and the left vitelline veins and by the persisting transverse anastomosing venous channels between them.

The caudal portion of the right and the left vitelline veins lie on the corresponding side of the developing duodenum and are communicated to each other by three transverse venous channels, proximal, intermediate and distal. The proximal and the distal anastomosing channels pass in front of the duodenum whereas the intermediate one passes dorsal to the duodenum. The portion of each vitelline vein extending from the cranial or proximal transverse venous channel to the liver is called the *vena advehens*. Subsequently, the venous channels from the mid-gut (superior mesenteric) and the fore-gut (splenic) join with the left vitelline vein opposite the intermediate anastomosing channel. Subsequently, both the right and the left vitelline veins together with the caudal, ventral transverse anastomosing channel retrogress completely; the left vitelline vein between the intermediate and the proximal anastomosing channels also retrogress.

The right vena advehens becomes the right branch of the portal vein whereas the left vena advehens together with the cranial ventral anastomosing channel forms the left branch of the portal vein. The trunk of the portal vein is formed by a small segment of the persistent left vitelline vein opposite the intermediate dorsal transverse anastomosing channel, the dorsal anastomosing channel itself and by the persistent right vitelline vein between the intermediate and the proximal transverse anastomosing channels.

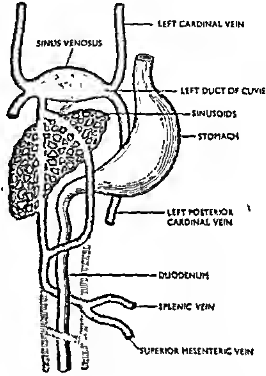


Fig. 657. The fate of the vitelline veins. Note the development of portal vein.

Splenic vein. It is one of the largest tributary of the portal vein and drains the stomach, spleen, pancreas, the descending colon, pelvic colon, rectum and most of the anal canal except its extreme lower part and ends by joining with the superior mesenteric vein to form the portal vein.

It is formed by the union of the five or six smaller veins which emerge from within the spleen at its hilum. It runs backwards and medially within the lieno-renal ligament to the front of the kidney, then it runs to the right to reach the posterior surface of the body of the pancreas where it is contained in a groove and runs transversely to the right below the splenic artery. Reaching the back of the neck of the pancreas it joins with the superior mesenteric vein to form the portal vein.

Tributaries:

(1) Short gastric.
(2) Left gastro-epiploic.
(3) Pancreatic—consist of several small veins which drain the pancreas.
(4) Inferior mesenteric.

Short gastric veins. They form a series of small veins which drain the blood from the left portion of the greater curvature of the stomach. They run backwards within the gastro-splenic ligament towards the hilum of the spleen and terminate into the splenic vein or into one of its main tributaries.

Left gastro-epiploic vein. It lies within the two layers of the greater omentum along the greater curvature of the stomach and runs from the right to the left. It enters into the gastro-splenic omentum and runs towards the hilum of the spleen where it ends by opening into the splenic vein.

Inferior mesenteric vein. It begins as a continuation of the superior rectal vein opposite the level of the pelvic brim and ascends upwards into the abdomen by crossing superficial to the left common iliac vessels. In its course upwards it lies in

front of the left psoas major muscle and crosses superficial to the inferior and superior left colic arteries and left testicular or ovarian vessels and intervenes between the inferior mesenteric artery and the abdominal aorta on the right side and the left ureter on the left side. Finally it passes deep to the duodeno-jejunal flexure and crosses in front of the left renal vein and ends by opening into the splenic vein behind the body of the pancreas.

Tributaries:

(1) Superior left colic.
(2) Inferior left colic.

The superior left colic vein drains the upper part of the descending colon and the left colic flexure. The *inferior left colic veins* drain the pelvic and the iliac portion of the descending colon.

The *superior rectal vein* drains the whole of the rectum and the greater part of the anal canal except its lower part. After being formed by the union of the tributaries from the rectal venous plexuses the superior rectal vein accompanies the superior rectal artery and runs upwards through the pelvic mesocolon to the brim of the pelvis where it becomes continuous with the inferior mesenteric vein by crossing the left common iliac vessels.

The *pancreatic veins* are numerous small veins which emerge out from the substance of the pancreas and at once terminate into the splenic vein.

Superior mesenteric vein. It is the largest tributary of the portal vein and begins in the right iliac fossa by the union of the appendicular and anterior and posterior caecal veins and by ascending upwards and to the left it ends by joining with the splenic vein behind the neck of the pancreas to form the portal vein. In its course it lies on the right side of the superior mesenteric artery and crosses superficial to the right ureter, right testicular or ovarian vessels, right psoas major muscle, inferior vena cava and the third part of the duodenum. Finally it ascends in front of the uncinate process of the head of the pancreas to reach the back of the neck of the pancreas where it terminates by joioing with the splenic vein to form the portal vein.

Tributaries:

(1) Appendicular.
(2) Anterior and posterior caecal.
(3) Jejunal and ileal.
(4) Ileo-colic.
(5) Right colic.
(6) Middle colic.
(7) Pancreatico-duodenal veins.
(8) Right gastro-epiploic vein.

The **appendicular** and the **anterior and posterior caecal veins** follow the corresponding branches of the superior mesenteric artery and are united together to form the superior mesenteric vein in the right iliac fossa. The **jejunal** and **ileal veins** drain the greater part of the small intestine and follow the corresponding branches of the superior mesenteric artery and end by joining with the superior mesenteric vein at the root of the mesentery. The **ileo-colic** and the **right colic** veins end into the superior mesenteric vein immediately below the third part of the duodenum while the **middle colic vein** terminates into it in front of the uncinate process of the pancreas. The **pancreatico-duodenal veins** drain the head of the pancreas and the adjoining portions of the duodenum and terminate into the superior mesenteric vein near its termination. The **right gastro-epiploic vein** drains both surfaces of the stomach and lies in between the two layers of the greater omentum and follows the greater curvature of the stomach from the left to the right. It ends in the superior mesenteric vein near its termination.

Right gastric vein. It lies in the right part of the lesser curvature of the stomach in between the two layers of the lesser omentum. It drains both the surfaces of the stomach, receives the pre-pyloric vein and finally ends in the portal vein as it lies in the lesser omentum.

Left gastric vein. It follows the left gastric artery to the gastric end of the oesophagus from which it receives some tributaries and then it turns backwards and passes to the left to end into the portal vein as it passes into the lesser omentum.

Cystic vein. It drains the gall-bladder and is formed by the union of the tributaries which accompany the branches of the cystic artery. It runs along with the cystic duct and ends by terminating into the right branch of the portal vein.

Para-umbilical vein. It follows the ligamentum teres hepatis from the umbilicus to the left part of the porta hepatis where it ends by opening into the left branch of the portal vein. Around the umbilicus it communicates with the superficial veins of the abdomen (superficial epigastric).

THE SUPERFICIAL VEINS OF THE INFERIOR EXTREMITY

The superficial veins of the inferior extremity begin in the dorsal and plantar networks.

The superficial veins of the sole of the foot form a fine network of plexus immediately beneath the skin and from this plexus three veins arise, anterior, medial and lateral. The anterior branch joins with the transverse venous arch which lies in the furrow at the roots of the toes. The medial and lateral branches pass round the sides of the foot to open into the great and small saphenous veins respectively. The transverse arch at the roots of the toes receives plantar digital veins from the toes and it communicates by intercapitular veins with the venous arch on the dorsum of the foot.

The superficial veins of the dorsum of the foot form a venous network beneath the skin and the superficial branches of the musculocutaneous nerve and the anterior tibial nerve. The dorsal digital veins from the contiguous sides of the interdigital space unite to form four dorsal metatarsal veins which further unite together to form the dorsal venous network. It ends, medially, by uniting with the medial marginal vein of the great toe to form the great (long) saphenous vein and laterally, by joining with the lateral marginal vein of the little toe to form the small or short saphenous vein.

Great (Long) saphenous vein. The great (long) saphenous vein is the largest vein in the body and is formed by the union of the medial part of the dorsal venous network and the medial marginal vein. It ends in the femoral vein about 3 cm. below the inguinal ligament. It ascends upwards in front of the medial malleolus of the tibia and then runs obliquely upwards across the medial surface of shaft of the tibia to gain its medial border. Then it ascends upwards along the posterior part of the medial condyles of the tibia and the femur from where it runs upwards along the medial aspect of the thigh and about 3 cm. below the inguinal ligament it pierces the cribriform fascia and the medial margin of the femoral sheath and ends in the femoral vein.

In the leg it is accompanied by the saphenous nerve. Behind the knee joint it accompanies the saphenous branch of the descending genicular artery and at the thigh it runs along with branches of the medial cutaneous nerve of the thigh. The great (long) saphenous vein is provided with numerous valves.

Valves. The great (long) saphenous vein is provided with numerous valves and their number vary from 6 to 25. The position of the valves also vary considerably but the one, which is present at the mouth (at the point where it joints with the femoral vien) of the great (long) saphenous vein, is fairly constant. Below this at a distance varying from 1 to 12 cm. there is another valve. The other valves present,

vary considerably in number as well as in position. According to Kampmeier and Birch there is one valve at every 6.6 cm. of the vein on an average above the knee.

Communications. In the thigh the great saphenous vein is communicated to the femoral vein by perforating veins (perforators) which perforates the deep fascia opposite the region of the adductor canal. A vein, the thoraco-epigastric vein communicates the superficial epigastric or femoral vein with the lateral thoracic vein and thus establishes communication between the superior and inferior venae cavae and helps in the collateral circulation in case of obstruction in any one of them. *Opposite the knee joint* it is communicated with the popliteal vein through a plexus of veins connected with the genicular veins. *At the leg* the great saphenous vein is communicated to the small (short) saphenous vein, and to the anterior and posterior tibial veins through perforating veins.

Surgical Importance. The great saphenous vein in often affected by varicosity due to either inefficiency of its valves or due to its holding a long column of blood against gravity.

Tributaries:

(1) Cutaneous veins from the plantar aspect of the foot.
(2) Some cutaneous veins of the leg.
(3) Accessory saphenous vein from the thigh.
(4) Superficial epigastric.
(5) Superficial external pudendal.
(6) Superficial circumflex iliac.

Short saphenous vein. It is formed by the union of the lateral marginal vein and the lateral part of the dorsal venous network. It at first runs upwards along the lateral side of the tendocalcaneus and then accompanied by the sural nerve it passes along the middle of the back of the leg and pierces the deep fascia in the popliteal fossa about 1 to 3 inches above the knee joint and ends in the popliteal vein. It is provided with numerous valves.

It receives several veins from the leg and superficial veins from the sole and dorsum of the foot and some deep veins from the dorsum of the foot. It freely communicates with the great (long) saphenous vein.

Dorsal venous arch. This is the most superficial structure and lies opposite the middle of the dorsum of the foot and is formed by the four dorsal metatarsal veins from the inter-matatarsal spaces and by the digital veins from the medial side of the great toe and from the lateral side of the little toe. Continued upwards from its medial end is the great (long) saphenous vein and from its lateral end is the short saphenous vein.

THE DEEP VEINS OF THE INFERIOR EXTREMITY

The deep veins of the inferior extremity follow the arteries and their branches and are named after the names of the accompanying arteries. They commence in the digits on the plantar aspects and follow up the limb.

The plantar digital veins begin from a venous plexus on the plantar aspect of the digits, communicate with the dorsal digital vein and running backwards they unite at the proximal part of the interdigital cleft to form *four plantar metatarsal veins.* The plantar metatarsal veins run backwards along the inter-metatarsal spaces and coming in close relation with the deep plantar arch formed by the lateral plantar artery and arteria dorsalis pedis, they are united together to form the *deep venous plantar arch.* Two veins, *lateral* and *medial plantar veins* run backwards from the corresponding side of the arch, accompany the lateral and the medial plantar arteries respectively and reaching behind the medial malleolus they unite together to form the *posterior tibial* *eins* which ascend upwards along the posterior tibial artery and after joining with

the peroneal vein reach the lower border of the popliteus where it joins with the anterior tibial vein to form the *popliteal vein*. The medial and the lateral plantar veins communicate freely with the great and the short saphenous veins respectively.

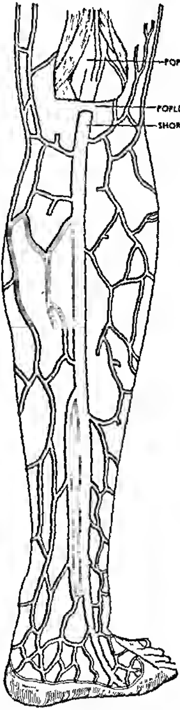


Fig. 658. The superficial vein of the inferior extremity. (Seen from behind).

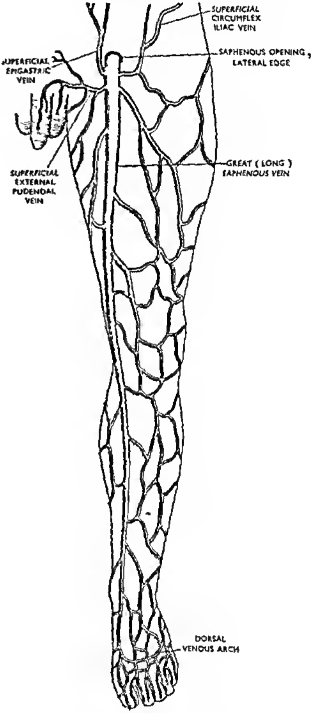


Fig. 659. The superficial veins of the inferior extremity. (Seen from the front).

Anterior tibial veins. They begin as venae comitantes of the arteria dorsalis pedis and then ascend upwards following the anterior tibial artery. Reaching the upper border of the interosseous membrane they pass backwards through the gap in this part of the interosseous membrane and reach the posterior compartment of

the leg and finally end by joining with the posterior tibial veins to form the *popliteal vein*.

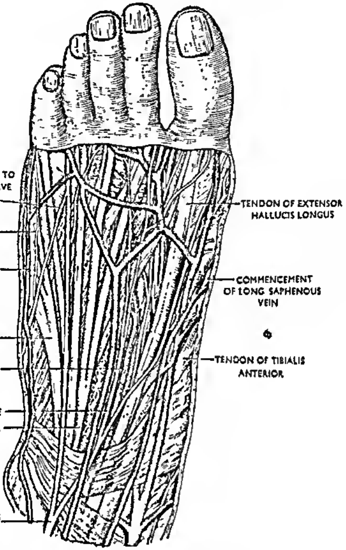


Fig. 650. The dorsum of the right foot. From the dissection hall, N. R. Sircar Medical College, Cal; with the kind permission from the Prof. of Anatomy.

Popliteal vein. It is formed by the union of the anterior and the posterior tibial veins at the lower border of the popliteus muscle. It then ascends through the popliteal fossa and finally enters into the opening in the adductor magnus opposite the junction of the middle-third and the lower-third of the thigh along with the popliteal artery to form the *femoral vein.* The popliteal vein crosses superficial to the popliteal artery from lateral to the medial side from above downwards in its course through the popliteal fossa.

Femoral vein. It begins as a continuation of the popliteal vein at the opening of the femoral artery at the adductor magnus and then ascends upwards through the adductor canal and the femoral triangle in company with the femoral artery and finally becomes continuous with the external iliac vein opposite the level of the inguinal ligament. In the lower part of the adductor canal the femoral vein lies posterolateral to the femoral artery and in the upper part of the adductor canal and opposite

the apex of the femoral triangle the vein lies posterior to the artery; in the upper part of the femoral triangle it lies medial to the femoral artery.

Tributaries:

Great (long) saphenous vein. Vena profunda femoris accompanies the arteria profunda femoris. Several small tirbutaries from the muscles. *Medial* and *lateral circumflex femoral veins*—accompany the corresponding arteries.

THE LYMPH NODES AND LYMPHATIC PATHWAYS

General consideration. The lymph nodes and the lymph vessels together constitute the lymphatic system in which the lymph vessels form minute channels which carry lymph, a clear fluid, to the lymph nodes which are solid, oval or rounded intermediate bodies in the pathways of the lymph vessels in their ultimate destination to the vein. The lymphatics like the blood vessels are closed system of minute channels which partially drain the tissue fluid from the tissues as lymph and convey the same (lymph) to the blood. The intermediary lymph nodes in the pathways of the lymphatics act as filters through which the lymph percolates before their final discharge into the venous blood.

Origin of lymph and the lymphatics. Blood vessels being the closed system of tubes no tissues, except perhaps the spleen, come in direct contact with the blood and the tissues get their nutrition through the medium of tissues fluid derived from the blood from the capillaries. As the walls of the capillaries behave like a permeable membrane crystaloids in solutions pass through the capillary walls by hydrostatic pressure at the arterial end of the capillaries, while at the venous end of the capillaries, due to increased osmotic pressure (fluids having been passed out of capillaries) within the capillaries, most of the tissue fluid returns back to the capillaries. The remaining portion of the tissue fluid (the nutrient fluid that is left behind after it has passed back to the capillaries at their venous end) which cannot pass back to the capillaries is collected in the lymphatic capillaries which appear as minute closed channels in the connective tissue, in between the cells or between groups of cells. The fluid that collects in the lymphatic capillaries is the *lymph.* It is so named because (lymph—clear water) the fluid resembles like clear water. The cells of the tissues after being bathed by the tissue fluid, which provide nourishment to them, eliminate their metabolic products in the same and the fluid then mainly passes back to the venous end of the capillaries and partly to the lymphatics.

N.B.—The composition of the lymph of the lymphatic capillaries and the tissue fluid is not same but the two fluids differ from each other in their protein content. The protein content of the lymph is almost equal to that of blood plasma and varies from 4 to 6 per cent while the protein content of the tissue fluid as determined from the oedema fluid is less than ·2 per cent.

Distribution in the body. As the source of the lymph is from the tissue fluid which in turn is derived from the blood, all tissues which are supplied by blood vessels have their lymphatics *except the tissues of the central nervous system, bone marrow and the spleen.* The epidermis, cornea, the hyaline cartilage, the hairs and the nails have no blood supply and consequently they have no lymphatics. To summarise the following tissues have no lymphatics:

(1) The tissues of the central nervous system.
(2) The bone marrow.
(3) The spleen.
(4) Epidermis.
(5) Cornea.
(6) Hairs and nails.
(7) Hyaline cartilage.

The lymphatic vessels begin as **lymphatic** radicles which are blind at one end and form intricate network of **lymphatic plexuses** underneath the surface epithelium as *sub-epithelial lymphatic plexus.* **Larger lymph** vessels from these plexuses pass into the deeper zone to form another **plexus (Sub-cutaneous,** Sub-mucous plexuses etc.). Larger lymph vessels from the latter follow the course of the veins and form *collecting lymph vessels.* The collecting lymph vessels present a beaded appearance (when distended) due to the presence of closely set valves in their interior and they end by piercing the lymph nodes in their pathways. Fresh vessels arise from each lymph

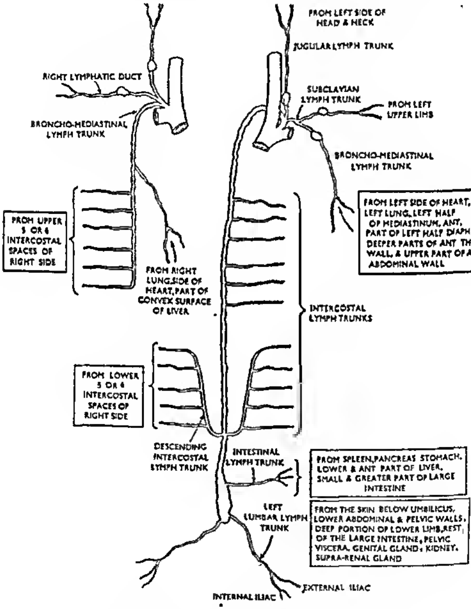


Fig. 661. The great lymphatic pathways. (Diagrammatic).

node and pass towards their termination in other subsidiary group of lymph nodes. The collecting lymph vessels which drain into the lymph node by piercing it at its periphery are known as *afferent lymph vessels* whereas the lymph vessels which drain

the node and emerge through its hilum to pass to the other subsidiary group of lymph nodes to form the *efferent lymph vessels*. The efferent lymph vessels from the most centrally placed lymph nodes of different lymphatic chain unite to form a *lymph trunk*. There are 5 lymph trunks namely, *subclavian, jugular, broncho-mediastinal (inter costal, mediastinal) lumbar*, and *intestinal*, which finally drain into the terminal lymph vessels, the *thoracic duct* and the right *lymphatic duct*. The thoracic duct ends by opening into the angle of junction between the left internal jugular vein and the left subclavian vein whereas the right lymphatic duct terminates into the corresponding venous angle on the right side.

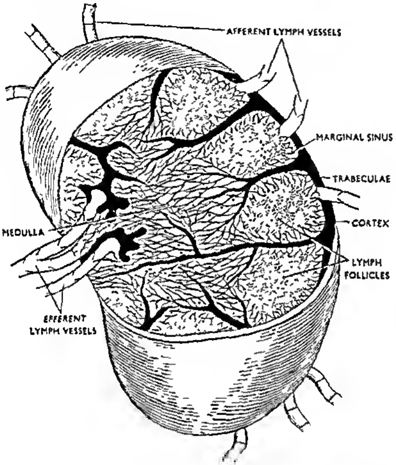


Fig. 662. The structural architecture of a lymph node. (Diagrammatic).

Lymphatics draining a particular part of the body are usually arranged into two main groups, superficial and deep. The superficial group of lymphatics drain the skin and the subcutaneous tissue and lie superficial to the deep fascia while the deep group of lymphatics drain the deeper structures and lie deep to the deep fascia. They run in streams and end into respective group of lymph nodes.

In the extremities and in the body walls the two groups of lymphatics, that is, the superficial and the deep groups, remain separated from each other by the deep fascia barrier. Except close to their termination in the regional lymph nodes they usually do not communicate with each other or if they do at all, communications are very much insufficient, as is seen in cases of obstruction when collateral circulation (through the other) fails to occur efficiently resulting in elephantiasis. In elephantias of leg there is obstruction in the superficial group of regional lymph nodes (into which the superficial group of lymph vessels terminate), as a result, lymph accumulates in the superficial group of lymph channels under tension because the obstructed

lymph cannot pass up collaterally through the deep lymphatics whose communication with the superficial lymphatics is sparse and insufficient.

Histological structure of lymphatics. Structurally the lymphatic capillaries, like the blood capillaries, are made up of a single layer of endothelium but *they differ from the latter (capillaries) in having no perithelial outer covering.* The endothelial cells are held together by intercellular cementing substances. Larger lymphatic vessels, like the blood vessels, consist of three tunics, the tunica adventitia, tunica media and the tunica intima from without inwards. The tunica adventitia consists of collagen fibres mostly which are disposed longitudinally but elastic fibres and smooth muscle fibres are also found in this layer intermingled with the collagen fibres. The tunica media consists of smooth muscle fibres and elastic fibres which are disposed circularly. The tunica intima is made up of elongated endothelial cells which rest on a subendothelial layer of elastic membrane. Fine non-medullated nerve fibres are also seen on the walls of the larger lymphatic channel and they extend as far as the tunica media.

Lymph nodes. These are oval, rounded or bean-shaped solid bodies found in course of the lymphatic pathways and are arranged either in groups or singly. They are commonly referred to as "lymph glands" but as they do not possess any secretion the more scientific nomenclature "Lymph nodes" should be applied to them. Each lymph node presents a constriction in its general outline on one side or the other which is known as the *hilum* through which the blood vessels and nerves enter and efferent lymph vessels leave the substance of the lymph node. The afferent lymph vessels penetrate obliquely into the substance of each node at the circumferential periphery at different points and carry the lymph into it. When sectioned each node is found to consist of a lighter periphery known as the *cortex* and a darker central part known as the *medulla.* The cortical substance is found to be absent in the region of the hilum where the medullary substance forms the surface tissue.

Histological structure. Structurally each lymph node consists of an outer denser cortex, an inner less dense medulla and a surrounding connective tissue capsule. Into the cortex are found aggregated masses of deeply staining lymphocytes, each having a central paler zone, known as the *lymphatic follicle or nodule.* The paler zone in the centre of each follicle is the *germinal centre.* The connective tissue capsule consists mostly of collagen fibres, a few fibroblasts and some elastic fibres. It also contains some smooth muscle fibres, particularly in some animals. From the deep aspect of the capsule fibrous septa are given off which divide the substance of the node into different smaller compartments towards its peripheral zone. Towards the central zone each fibrous septum breaks up into finer and finer ramifications which anastomose with one another forming a fine *connective tissue reticulum.* Thus the substance within the central zone fails to show definite compartmental groupings and instead it looks to be more diffuse.

Each peripheral compartment is filled up with dense collection of lymphocytes which constitutes the *lymph follicle* or *nodule.* In a stained preparation the centre of each lymph follicle looks to be paler in colour in contrast to the deeply staining peripheral cells and is known as the *germinal centre* or *secondary nodule.* The germinal centre is composed of larger cells which are loosely packed and some of them show signs of active proliferation in the form of mitotic division and it is for this reason the name "germinal centre" has been applied to this portion of the lymph follicle. Between each lymph follicle and the capsule is a narrow zone of loose tissue which forms the *marginal lymph sinus* in which the afferent lymph vessels end by piercing it obliquely. The marginal lymph sinus follows the course of the septum from the capsule to their finer ramifications and ultimately it drains into the efferent lymph vessels leaving the lymph node at its hilum and thus a closed system of lymph path is established within the lymph node. The lymph sinuses within the lymph node are traversed by fine networks of connective tissue fibres which are lined by *reticular cells.* These reticular cells are highly phagocytic and are continuous with the endothelial cells of the efferent and afferent lymph vessels of the lymph node. These

phagocytic cells form the macrophage system of cells. Scattered amongst the reticular fibres there are also some other macrophage system of cells.

Circulation of lymph. The lymph from the tissue spaces gain access into the lymphatic radicle and then is carried to the larger lymphatic vessels and having passed through intermediary lymph nodes in the lymphatie pathways the lymph is finally conveyed to the blood by the thoracie duct and the right lymphatic duct (has already been stated). The circulation is carried on by the following mechanism.

(1) Capillary pressure induces flow of the lymph into the lymphatic radicles. (2) The endothelial cells of the lymph capillaries by their contractile power (driving force) force the fluid up into the lymphatic channels. (3) The smooth muscles surrounding the larger lymphatics also, by their contractions, keep up the circulations going. (4) The valves within the larger lymphatic channels prevent falling down of the lymph column, particularly when it is to work against gravity. Besides these (5) the squeezing action of muscles and (6) suction action of the veins at the root of the neck play an important role in the circulation of lymph. Moreover (7) increased intra-abdominal pressure during inspiratory movement tends to squeeze out the lymph from the abdomen into the thorax.

Rhythmic peristaltic contractions of the walls of the lymphatic vessels themselves squeeze the lymph into the lymph vessels.

In some birds and reptiles the lymph heart which is a muscular sac assists in lymph circulation.

Absorption through lymphatics. Absorption through the lymphatics takes place through the endothelial cells. It is believed that colloid and insoluble substances are absorbed by the lymphatics whereas crystaloid substances and substances having lower molecular weight (lower than that of serum albumen) are absorbed through the capillaries. From the above it is evident that lymphatics are more permeable than the capillaries.

Modes of lymphatic absorption. Having learnt about the nature of the lymphatic absorption it would be interesting to note as to how the lymphatic absorption takes place. From different experiments done by distinguished authors it is known that there are at least four methods by which absorption through the lymphatics occurs and the following is a brief outline of them.

(1) *By phagocytosis.* Insoluble substances when placed in the tissue spaces are taken up by the phagocytes which bore their way through the wall of the lymphatics into their lumen.

(2) *Absorption by a process of lymphatic pseudopodia.* When any foreign substance is placed in the tissue spaces close to a lymphatic vessel, pseudopodial processes are thrown out which are further prolonged to come in contact with the substance and the latter gets into the lumen of the vessel by the activity of the lining endothelial cells.

(3) *Absorption by a break in the continuity of the lymphatic wall.* Under some pathological conditions, such as inflamation and trauma, the wall of the lymphatic vessel may rupture thus allowing free access of the substances within their lumen.

(4) *Direct blood vessel to lymph vessel absorption.* Whenever a lymph vessel happens to lie in close contact with the wall of a permeable blood vessels, direct blood vessel to lymph vessel absorption is known to occur without any detectable impairment of the walls of the two vessels.

Functions of lymph nodes and lymphatics. As has already been stated lymphaties are greatly concerned (1) in the absorption of colloid and insoluble substances from the tissue spaces. (2) Foreign substances, cellular debrids and other matters are also removed from the tissue spaces by the lymphaties by different methods already described. (3) The lymphaties of the intestines are also concerned in the absorption of fat.

The lymph nodes act as (4) mechanical filters and keep back deleterious substances from gaining access to the blood. (5) The reticular cells lining the lymph

sinuses of the lymph nodes phagocytose bacteria and other substances and thus play important roles in the defensive mechanism of the body. (6) It is known that in cancers, cancerous cells permeate through the lymph vessels to the lymph nodes from where their further spread is temporarily withheld and thus the lymph nodes have limiting function in the spread of malignant diseases (Cancer). (7) The most important function of the lymph nodes is the production of lymphocytes.

Development of lymph vessels and the lymph nodes. All lymph vessels originate from five main lymph sacs which develop in close association with large veins. Two lymph sacs develop in association with the two internal jugular veins, two with iliac veins and one unpaired lymph sac develops on the posterior abdominal wall which later on forms the cisterna chyli. Although opinion differs as to the origin of these lymph sacs it is generally agreed that they arise as diverticula of the venous endothelium. By a process of budding of the endothelial cells of the regional lymph sacs extensive invasion of the tissues takes place and as a result, the original lymph sacs flow out to form intricate lymphatic pathways pervading almost all the tissues. Later on, the connections of all the lymph sacs with the veins, except the jugular sacs, disappear and thus explaining the termination of the thoracic and the right lymphatic ducts into the veins.

The lymph nodes develop along the course of the lymphatic pathways as follows: In the region where a lymph node is to appear the lymph vessels arrange in plexiform networks, in the interstices of which, there lie the mesenchymal cells. The mesenchymal cells proliferate and differentiate *in situ* into lymphocytes which are arranged into small compact masses. These compact masses of lymphocytes invaginate the lining endothelium of the lymph sinus and collectively give rise to the formation of the lymph node. The surrounding connective tissue condenses to form the connective tissue capsule of the node.

THE LYMPH NODES OF THE SUPERIOR EXTREMITY

The terminal lymph nodes of the superior extremity are the axillary group of lymph nodes, and the other outlying lymph nodes are the supratrochlear, infraclavicular and some isolated nodes that may be found along with the course of the deeper vessels of the limb. Thus the lymph nodes of the superior extremity have been discussed under the following heads:

The **supratrochlear lymph nodes** consist of one or two small lymph nodes situated above the medial epicondyle of the humerus on the deep facia in close relation with the basilic vein. Their afferents drain the anteromedial aspects of the hand and forearm whereas their efferents accompany the basilic vein and terminate into the lateral group of axillary lymph nodes.

The **infraclavicular lymph nodes** number about one or two and lie below the lateral one-third of the clavicle in the depth of the intermuscular furrow between the deltoid and the pectoralis major in close relation with the terminal part of the caphalic vein. Their afferents drain the anterolateral regions of the hand, forearm and the arm and accompany the caphalic vein. Their efferents pass mostly to the apical group of axillary lymph nodes by piercing through the clavipectoral fascia, but a few may terminate into the lower deep cervical lymph nodes by crossing over the clavicle.

Axillary lymph nodes. The axillary lymph nodes form a most important group which drains the breast, the upper limb, and the skin of the body from the umbilicus to the clavicle. They consist of 20 to 30 in number and are divided into five groups, anterior, posterior, lateral, central and apical.

(*a*) *Anterior or pectoral group.* They are 4 to 6 in number and lie along the lower border of the pectoralis minor along the lateral thoracic vessels. They receive lymphatics from the lateral and anterior aspects of the body above the umbilicus and also from the lateral half of the breast. Their efferents pass to join with the central and apical groups.

(*b*) *Posterior or subscapular group.* They lie along the subscapular vessels and vary from 6 to 7 in number. They receive afferents from the whole of the back and the lateral aspect of the body above the iliac crest and from the back of the neck. Their efferents join with the central and apical groups.

(c) *Lateral group*. They lie along the medial side of the axillary vein and vary from 4 to 6 in number. They receive all the lymphatics of the upper limb except those which accompany the cephalic vein. Their efferents join with the central and apical groups and a few with the lower deep cervical lymph nodes.

(d) *Central group*. They are 3 to 4 in number and lie in the fat filling the axilla. They have got no particular area of drainage but they receive afferents from the other axillary lymph nodes. Their efferents pass to join with the apical group of axillary lymph nodes.

(e) *Apical or deep infraclavicular group*. They are 6 to 12 in number. They are situated in the angular interval between the clavipectoral fascia in front, axillary vein behind and the first intercostal space below. They are of great importance because they receive some lymph vessels directly from the upper part of the breast and from the other parts of the breast indirectly through other subsidiary lymph nodes. They also receive lymphatics from the upper limb, which accompany the cephalic vein, *i.e.*, lymphatic draining the thumb, index finger and the outer side of the hand and forearm, and they also receive afferents from the other groups of axillary lymph nodes. Their efferents unite to form the *subclavian lymph trunk* which on the right side opens in the angle between the right subclavian and right internal jugular veins, and on the left side, into the thoracic duct. Some of them may pass to the lower deep cervical lymph nodes.

THE LYMPH NODES OF THE INFERIOR EXTREMITY

The terminal lymph nodes for the inferior extremity are the inguinal group of lymph nodes except those draining the deep structures of the gluteal and ischial regions which follow the superior and inferior gluteal arteries and terminate into the internal iliac group of lymph nodes after traversing though some intermediary nodes. The intermediary lymph nodes of the inferior extremity are the popliteal lymph nodes. Thus the lymph nodes of the inferior extremity can be discussed under popliteal lymph nodes and the inguinal lymph nodes.

The **popliteal lymph nodes** drain the deeper structures of (structures lying deep to the fascia crusis) the leg and receive some superficial lymphaties which accompany the short saphenous vein. They consist of 6 or 7 in number and are situated in the fat of the popliteal fossa in close relation with the popliteal vessels. Most of them lie along the sides of the popliteal vessels, one lies in front of them and intervenes between them and the back of the knee joint, and another lies at the termination of the short saphenous vein into the popliteal vein.

The efferents from the popliteal lymph nodes mostly run along with the femoral vessels and terminate into the deep group of inguinal lymph nodes but a few of them accompany the great saphenous vein and terminate into the superficial group of inguinal lymph nodes.

The **inguinal lymph nodes.** The inguinal lympb nodes lie immediately below the inguinal ligament in cases of adult and over the ligament and sometimes above the ligament (McGregor) in case of the infants. They consist of two groups, superficial, lying over the fascia lata and deep, lying beneath the fascia lata.

The superficial inguinal lymph nodes. They consist of two sets, a proximal or horizontal set lying immediately below and parallel to the inguinal ligament, and a distal or vertical set lying along the upper end of the great (long) saphenous vein.

(a) The proximal or horizontal set again consists of lateral and medial members. The lateral members receive the lymphatics from the buttock and the lateral half of the lower part of the abdomen below the umbilicus. The medial members of this group receive lymph vessles draining the skin of the penis, scrotum, perineum, from the mucous membrane of the anterior part of the urethra, the anal. circumanal region and the medial half of the lower part of the abdomen

umbilicus and also the lymph vessels which accompany the round ligament of the uterus, the lymphatics of the labia majora and the lower part of the vagina in case of female.

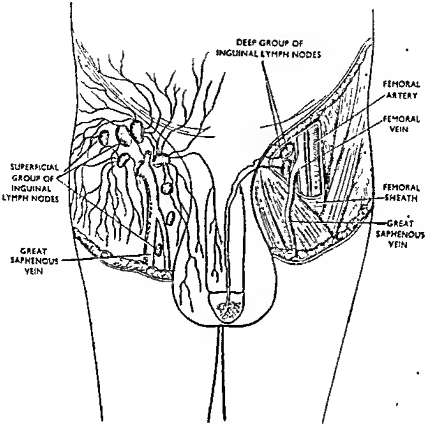


Fig. 663. The inguinal lymph nodes.

(*b*) The distal or the vertical set receives lymph vessels which accompany the great (long) saphenous vein. These lymph vessels drain the whole of the lower limb except that from the outer side of the dorsum of the foot, and the back and outer side of the leg. They also receive some lymphatics of the buttock, penis and the scrotum.

The efferents from the superficial inguinal lymph nodes pass to join with the external iliac group of lymph nodes. Some of them join with the deep inguinal lymph nodes.

The deep inguinal lymph nodes. They are 2 or 3 in number lying beneath the fascia lata on the medial aspect of the femoral vein. One lies in the femoral canal, one at the femoral ring and one at the junction of the great (long) sphenous vein with the femoral vein. They receive all the deep lymphatics accompanying the femoral vein, lymphatics from the glans penis in male and the clitoris in the female, and also some lymph vessels from the superficial inguinal lymph nodes.

The efferents from the deep inguinal lymph nodes join with the external iliac lymph nodes.

LYMPHATICS OF THE HEAD AND NECK

Lymphatics draining the head and neck pass through two set of lymph nodes, superficial and deep. The superficial set of lymph nodes drains the superficial tissues of the head and neck and give rise to efferent lymph vessels which terminate

in the deep group of lymph nodes. The deep group of lymph nodes forms the main chain of lymph nodes draining the head and neck and are called the deep cervical lymph nodes. They lie along the internal jugular vein in front of the prevertebral fascia behind the posterior border of the sternocleidomastoid muscle and extend from the base of the skull to the root of the neck. The main lymphatic trunk from the deep cervical lymph nodes at the root of the neck is called the *jugular lymph trunk* which ends by opening into the thoracic duct on the left side and into the angle of junction between the subclavian and the internal jugular veins on the right side.

Superficial group of lymph nodes. The following are the superficial groups of lymph nodes, each of which has its own territory which it drains and gives rise to efferent vessels which end into the deep cervical lymph nodes.

Occipital lymph nodes. The occipital lymph nodes are 2 or 3 in number and they lie on the trapezius muscle where it is pierced by the occipital artery and correspond to a point about an inch inferolateral to the inion. They drain the posterior part of the scalp.

Mastoid lymph nodes. One or two mastoid lymph nodes lie over the mastoid part of the temporal bone in company with the posterior auricular artery. They receive the afferents from the sides of the scalp and the auricle.

Superficial parotid lymph nodes. They lie superficial to the parotid fascia opposite the superficial temporal and the transverse facial arteries. They drain the scalp, auricle, eyelids and the cheek. Their efferents pass to the superficial cervical and the deep parotid lymph nodes.

Superficial cervical lymph nodes. They form a chain of lymph nodes which lie along the external jugular vein superficial to the sternocleidomastoid muscle.

Submandibular lymph nodes. They lie along the facial artery on the submandibular gland and intervene between it and the lower jaw. They receive afferents from the submental and the facial lymph nodes which are truly its extensions; they also receive lymph vessels from the face, cheek, nose, upper lip, gums, and tongue.

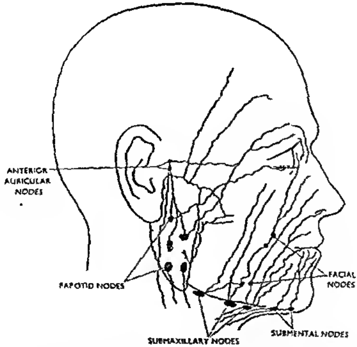


Fig. 664. The lymphatic drainage of the face. With kind permission from Prof. W. H. Hollinshed, Anatomy for the Surgeon, Vol. I, Paul B. Hoeber I.N.C.

Submental lymph nodes. They lie on the mylohyoid muscle below the symphysis menti and receive afferents from the chin, lower lip, and the tip of the tongue. Some of their efferents end in the sub-mandibular lymph nodes and some in the jugulo-omohyoid lymph nodes (deep cervical).

Facial lymph nodes. They are inconstant in their distribution and 1 or 2 may be found along the facial artery opposite the lower border of the jaw.

Deep cervical lymph nodes. The majority of the deep cervical lymph nodes lie under cover of the posterior border of the sternocleidomastoid although many of them extend forwards in the upper part of the anterior triangle and extend backwards beyond the posterior border of the sternocleidomastoid into the posterior triangle. All of them lie superficial to the prevertebral fascia which intervenes between them and the cervical and the brachial plexuses of nerves. The accessory nerve which lies between the prevertebral fascia and the investing layer of the deep cervical fascia is surrounded by these nodes both at its entrance into the sternocleidomastoid and at its exit from the same. The inferior belly of the omohyoid subdivides the deep cervical lymph nodes into upper and lower groups. A few lymph nodes of the upper group extend medially behind the nasal part of the pharynx and are known as the *retro-pharyngeal lymph nodes.* Those which lie immediately below the posterior belly of the digastric along the terminal part of the (common) facial vein come under the *jugulo-digastric group.* They receive afferents from the superficial lymph nodes and from the tongue. The lymph nodes lying above the posterior belly of the omohyoid where it crosses the internal jugular vein come under the *jugulo-omohyoid group.* They receive afferents from the superficial lymph nodes, from the upper deep cervical lymph nodes and from the tongue. Some of the lower deep cervical lymph nodes receive lymphatics from the axilla and the breast. Some of the forward extensions of the deep cervical lymph nodes are known as infrahyoid, prelaryngeal and para-tracheal groups. The *infrahyoid group* lies on the hyothyroid membrane and receives afferent vessels which accompany the superior laryngeal artery; they drain the upper part of the larynx as far as the vocal fold. The *prelaryngeal group* lies on the cricothyroid membrane while the *para-tracheal group* lies in the groove between the trachea and the oesophagus. They receive afferents from the larynx below the vocal fold, from the oesophagus and from the thyroid gland.

THE LYMPHATICS AND THE LYMPH NODES IN THE ABDOMINAL CAVITY

The lymph nodes of the abdominal cavity, as in elsewhere, are situated in close relation with the blood vessels. The main groups are situated along the abdominal aorta and the subsidiary groups are situated in relation with the smaller blood vessels which are descendants from the abdominal aorta. The main lymph nodes lie in close relation with the main branches of the abdominal aorta and they are placed anteriorly, posteriorly as well as at the sides in relation with the abdominal aorta and accordingly they are named as *pre-aortic, lateral aortic* (right and left) and *retro-aortic group of lymph nodes.*

Pre-aortic group of lymph nodes. These lymph nodes are situated in front of the abdominal aorta in relation with its three ventral branches namely, coeliac, superior mesenteric, and inferior mesenteric and they are named accordingly as the *coeliac, superior mesenteric* and *inferior mesenteric groups of lymph nodes.* Directly and indirectly through outlying and intermediary groups of lymph nodes they drain the whole of the gastro-intestinal tract below the diaphragm and also drain the spleen, pancreas and the liver and their efferents unite to form the *intestinal lymph trunk* which opens into the cisterna chyli.

The outlying lymph nodes in association with the coeliac group consist of three sets namely gastric, hepatic and pencreatico-splenic groups of lymph nodes.

The **gastric group** again consists of *left gastric, right gastro-epiploic* and the *pyloric groups of lymph nodes*. The left gastric group lies in relation with left gastric artery in between the two layers of the lesser omentum. The *right gastro-epiploic group*

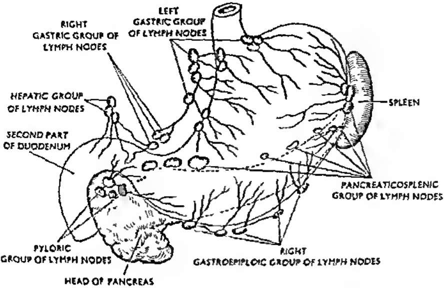


Fig. 665. The lymph nodes in relation to the stomach.

consists of 5 to 7 lymph nodes which lie in between the two layers of the greater omentum along with the right gastro-epiploic artery opposite the pyloric-half of the greater curvature of the stomach. The *pyloric group* of lymph nodes consists of 4 to 5 lymph nodes which lie in the angle between the first and the second parts of the duodenum in relation with the bifurcation of the gastro-duodenal artery.

The hepatic group of lymph nodes lies along the course of the stem of the hepatic artery and lies in between the two layers of the lesser omentum. Some of its members extend up to the porta hepatis along with the bile duct. One member of this group that lies into relation to the neck of the gall bladder is called the cystic lymph nodes.

The **pancreatico-splenic group of lymph nodes** lies in association with splenic artery along the posterior surface and the upper border of the body of the pancreas ; the *superior mesenteric group of lymph nodes* lies around the origin of the superior mesenteric artery and is continuous with the mesenteric lymph nodes lying along the root of the mesentery. These lymph nodes drain the territories of the gastro-intestinal tract supplied by the superior mesenteric artery.

The *inferior mesenteric group of lymph nodes* lies on either side of the origin of the inferior mesentric artery. They drain the area of the gastro-intestinal tract supplied by the inferior mesenteric artery.

Lateral aortic group of lymph nodes. They consist of two chains, right and left, which lie on the corresponding side of the abdominal aorta. Each group lies in front of the medial margin of the psoas major muscle and the crus of the diaphragm. The right chain is closely related to the right margin of the inferior vena cava and in front of the latter opposite the termination of the right renal vein.

Retro-aortic lymph nodes have no particular area of drainage and they are believed to be the spread-out members of the lateral aortic group of lymph nodes. They receive some efferents from the lateral aortic group.

Below the bifurcation of the abdominal aorta there are three bilateral sets of lymph nodes and a single posterior set. The bilateral sets are common iliac, external and internal iliac groups of lymph nodes. The posterior set is the sacral set. These lymph nodes drain the pelvic viscera and its parieties..

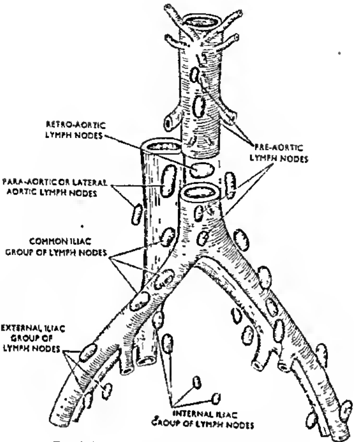


Fig. 666. The aortic groups of lymph nodes.

The **common iliac group of lymph nodes** consists of three sets, lateral, medial and posterior. The lateral set consists of two nodes which lie along the lateral side of the common iliac artery. The medial set also consists of two nodes which lie on the promontory of the sacram and often called the nodes of the promontory. The posterior set consists of 2 to 4 lymph nodes which lie behind the artery.

The *internal iliac* or the *hypogastric group of lymph nodes* lies behind the pelvic fascia opposite the origins of the different branches from the internal iliac artery. They drain the territory supplied by the corresponding arteries. Their efferents pass to the common iliac group of lymph nodes.

The *external iliac group of lymph nodes* also consists of three sets of lymph nodes, lateral, medial and intermediate. The lateral set lies along the lateral side of the external iliac artery and are in series with the lateral group of common iliac group and the superficial and the deep inguinal lymph nodes. They receive afferents from the superficial and the deep groups of the inguinal lymph nodes, from the glans penis or clitoris which pass through the inguinal canal and from the abdominal walls supplied by the two branches of the external iliac, that is, the inferior epigastric and the deep circumflex iliac arteries. The outlying lymph nodes present along these vessels are called the epigastric lymph nodes. The intermediate set lies behind the external iliac artery. They receive afferents from the pelvic viscera such as bladder, prostate, upper part of vagina and the cervix uteri. The medial set lies along the medial margin and in front of the artery and number about 3 or 4 lymph nodes. They are in series with the inguinal groups of lymph nodes. In addition to the lymphatics from the inguinal groups of lymph nodes they drain

the glans penis or clitoris, abdominal wall and some of the pelvic viscera, membranous part of male urethra and some of the internal iliac group of lymph vessels.

The sacral lymph nodes number about 5 or 6 lymph nodes and they lie in the concavity of the sacrum close to the middle line. They drain the prostate, rectum and their efferents pass to the internal iliac and lateral aortic groups of lymph nodes.

THE LYMPHATICS AND THE LYMPH NODES OF THE THORAX

The lymphatics of the thorax are arranged into groups of lymph vessels which drain the thoracic walls or the parieties and the thoracic viscera and accordingly they may conveniently be divided into the *parietal* and *visceral lymphatics*.

The **parietal lymphatics** are further subdivided into superficial and deep sets of lymph vessels which drain into the regional lymph nodes. The superficial sets of lymph vessels drain the skin and the subcutaneous tissues whereas the deep set drains the deeper structures of the thoracic walls. Thus the parietal lymphatics may be discussed as below:

A. The lymphatics and the lymph nodes which drain the superficial tissues of the thoracic walls. (*a*) Majority of the lymph vessels draining the anterior and posterior walls end into the axillary groups of lymph nodes.

(*b*) Some of the vessels from the pectoral region pass upwards, cross the clavicle and end in the lower cervical group of lymph nodes.

(*c*) Lymph vessels from the medial side of the anterior thoracic wall freely communicate with the lymph vessels of the opposite side.

(*d*) Lymph vessels draining the superficial aspect of the latissimus dorsi and the trapezius form 8 to 10 lymph vessels which end in the subcapsular group of axillary lymph nodes.

B. The lymphatics and the lymph nodes of the deep tissues of the thoracic walls consist of internal mammary, intercostal and diaphragmatic groups of lymph nodes.

The **internal mammary lymph nodes** consist of two sets of small lymph nodes which accompany the internal mammary artery. They receive afferents from deeper part of the anterior abdominal wall above the umbilicus, from the upper surface of the liver and from the deep part of the anterior thoracic wall. Their efferents unite to form a single trunk which may end by opening at the angle of junction between the subclavian and internal jugular vein or may end in thoracic duct on the left side or in the right subclavian trunk on the right side.

The **intercostal group** consists of two sets of lymph nodes, one on each side of the vertebral column, which are present in the posterior wall of the thoracic cavity in relation to the heads of the ribs. They receive afferents from the posterolateral aspect of the thoracic wall. Their efferents end in the following ways: (i) those from the lower 4 to 5 spaces unite to form a single trunk which ends in the cisterna chyle or the commencement of the thoracic duct; (ii) those from the upper spaces on the left side end in the thoracic duct, and on the right side, in the right lymphatic duct.

The **diaphragmatic groups of lymph nodes,** are anterior, right and left lateral, over the thoracic surface of the diaphragm. The *anterior group* is situated behind the xiphoid process and receive afferents from the liver and from the anterior part of the diaphragm. Their efferents pass to the internal mammary lymph nodes. The *lateral sets* are situated on the corresponding lateral aspect and receive afferents from the lateral and middle aspects of the diaphragm on the right side and from the convex surface of the liver. Their efferents pass to the posterior mediastinal lymph nodes.

The **visceral lymph nodes** constitute the most important group of lymph nodes and consist of (*a*) *innominate group of lymph nodes*, (*b*) *posterior mediastinal group*

of lymph nodes, (c) the tracheo-bronchial group of lymph nodes, and (d) pulmonary lymph nodes.

(a) **The innominate lymph nodes** are situated in the anterior part of the superior mediastinum in relation to the front of the brachiocephalic (innominate) vein and the great vessels from the arch of aorta. They receive afferents from the pericardium, thymus gland and also some of the diaphragmatic (lateral) lymph vessels. Their efferents unite with those of the tracheo-bronchial lymph nodes to form the corresponding broncho-mediastinal lymph trunk.

(b) **Posterior mediastinal lymph nodes** lie in relation to the oesophagus and the descending thoracic aorta in the posterior mediastinum. They receive afferents from oesophagus, pericardium and the adjacent structures. Their efferents end in the thoracic duct, some may end in the tracheo-bronchial lymph nodes.

(c) **The tracheo-bronchial lymph nodes** are the most important group of lymph nodes and they lie in relation to the trachea, the bronchus and the lung. They consist of five groups of lymph nodes as follows:

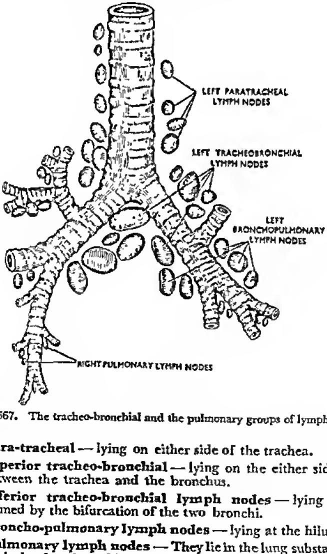


Fig. 667. The tracheo-bronchial and the pulmonary groups of lymph nodes.

(i) **Para-tracheal** — lying on either side of the trachea.

(ii) **Superior tracheo-bronchial** — lying on the either side in the angle between the trachea and the bronchus.

(iii) **Inferior tracheo-bronchial lymph nodes** — lying in the angle formed by the bifurcation of the two bronchi.

(iv) **Broncho-pulmonary lymph nodes** — lying at the hilum of the lung.

(v) **Pulmonary lymph nodes** — They lie in the lung substance in relation with the finer bronchi.

The tracheo-bronchial lymph nodes drain the lungs, trachea and the heart. Their efferents unite with those of the innominate lymph nodes to form the right and left broncho-mediastinal lymph trunks. The right broncho-mediastinal lymph trunk usually opens into the right lymphatic duct and the left opening in the thoracic duct.

N.B. — Dust and carbonaceous particles gain their access into the lungs through air by breathing and this is particularly so in case of city dwellers. From the lung alveoli, these particles pass through its wall into the lymph capillaries. As the lymph containing these particles passes through the lymph nodes the cells of the latter remove these particles which are subsequently deposited in their substance and the stroma of the node and as a result, the node gradually becomes darker and darker as life continues. In tuberculosis these nodes are almost invariably affected and once a caseous node bursts into a bronchus the disease will spread rapidly into the different parts of the lung.

The **cisterna chyli** is an elongated lymphatic receptacle which ends into a blind extremity inferiorly but is continuous upwards as the thoracic duct and is formed by the confluence of the three great lymph trunks, the right and the left lumbar and the intestinal lymph trunks.

Size and form. It is an *elongated oval body* which is broader below and gradually becomes narrower to become continuous with the thoracic duct. It is about 2 to 3 inches long and measures transversely about to of an inch at its widest part. However, in some cases, it is either irregular in its form or it is split into a plexus of lymphatics.

Situation. It is situated opposite the bodies of the first and the second lumbar vertebrae between the abdominal aorta on the left side and the right crus of the diaphragm and the azygos vein on the right side.

Relations. *Posteriorly* it is related of the front of the bodies of the first and the second lumbar vertebrae together with the anterior longitudinal lighment and the first and the second lumbar arteries. *Anteriorly* it is related to the abdominal aorta on the left side and the azygos vein and the right crus of the diaphragm on the right side. To the right is the right crus of the diaphragm and to the left is the left crus of the diaphragm.

Tributaries

Intestinal lymph trunk.
Right and left lumbar lymph trunks.

Development. It develops from the primitive lymph sacs situated on the posterior wall of the abdominal cavity.

The **thoracic duct.** The thoracic duct is the largest lymphatic pathway which carries lymph or chyle from the different parts of the body to the blood.

Course. It varies from 14 to 18 inches in length. It begins opposite the twelfth thoracic vertebra as a direct continuation of the cisterna chyle and enters the thorax through the aortic opening in the diaphragm. In the thorax it at first ascends upwards in the posterior mediastinum in front of the vertebral column on the right side of the median plane, then opposite the level of the fourth thoracic vertebra it crosses to the left of the median plane and ascends upwards in the superior mediastinum to the root of the neck. It then enters the neck through the thoracic inlet and opposite the transverse process of the seventh cervical vertebra it curves upwards and laterally and finally descending downwards it ends by opening into the angle of junction between the left subclavian and the left internal jugular veins.

Relation — (Thoracic part).

In the posterior mediastinum it lies in front of the lower eight thoracic vertebrae, anterior longitudinal ligament, right aortic intercostal arteries and the terminal

portions of the hemiazygos veins. In the superior mediastinum it lies in contact with the mediastinal pleura. Anteriorly, it is in relation to the diaphragm only at the lower part of the posterior mediastinum and throughout the rest of its course in the posterior mediastinum it lies behind the oesophagus. In the superior mediastinum it lies at first behind the arch of the aorta, then it ascends upwards behind left subclavian artery. In the posterior mediastinum it lies between the azygos vein on the right side and the descending thoracic aorta on the left side. In the superior mediastinum it lies on the left side of the oesophagus.

Relation — (Cervical portion).

It enters the neck behind the left subclavian artery and passes laterally in front of the left vertebral system (vertebral artery, vertebral vein and sympathetic trunk) and behind the left carotid system (common carotid artery, vagus nerve and internal jugular vein). Then it crosses in front of the scalenus anterior muscle and the phrenic nerve and finally descending in front of the left subclavian artery it ends in the angle of junction between the left subclavian and the left internal jugular veins.

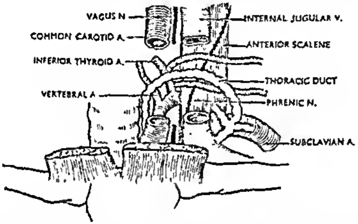


Fig. 668. The relations of the thoracic duct in the neck. With kind permission from Prof. W. H. Hollinshed, Anatomy for the Surgeon, Vol. 1, Paul B. Hoeber I.N.C.

The thoracic duct receives lymph from all the parts of the body except the right side of the head, neck, and the thoracic wall and right superior extremity, right part of the heart, right lungs and pleura and the convex surface of the liver.

Tributaries—

(i) At its origin it is joined by a descending trunk which drains the posterior intercostal lymph nodes of the lower 6 or 7 intercostal spaces on either side.
(ii) Lymph trunk draining the posterior mediastinal lymph nodes and the posterior intercostal lymph nodes of the left upper six intercostal spaces.
(iii) Left jugular trunk draining the left side of the head and neck.
(iv) Left subclavian lymph trunk from the left superior extremity.
(v) Left broncho-mediastinal lymph trunk (not usual).

VISCERAL SYSTEM OR SPLANCHNOLOGY

DIGESTIVE SYSTEM

All living organisms require food in some form or other which provides energy for the maintenance of life, growth and repair of the tissues. The digestive system is a combination of organ system in the body mechanics which is conveniently adapted for ingestion, digestion, and assimilation of food and for elimination of the non-absorbable food residue, that is, the stool or the faeces. Basically, in all vertebrates, the digestive system consists of a long tubular structure with two openings, one at each end; one of these openings serves for the intake of food and the other for the exit of the non-absorbable food residue, the stool. The opening that is meant for the entrance of the food is known as the *mouth* and that which is meant for the exit of the stool is known as the *anus*. The portion that intervenes between the mouth and the anus is variously oriented to be subdivided into different functional units, each subserving its own function as a helping hand for its successor with the ultimate object of digestion, assimilation and elimination of waste products. The section between the mouth and the anus is thus subdivided into pharynx and oesophagus, stomach, small intestine and the large intestine. The small intestine is further subdivided into duodenum, jejunum and ileum, and the large intestine into caecum, appendix, ascending colon, transverse colon, descending colon, pelvic colon, rectum and anal canal. The whole tract beginning from the mouth to the anus is known as the *alimentary canal*. Elaborate glandular organisation is associated with the alimentary canal which helps variously in the process of digestion, assimilation and elimination of food residue, and the whole alimentary canal together with its associated glands subserving the common purpose as stated above is included in *digestive system*.

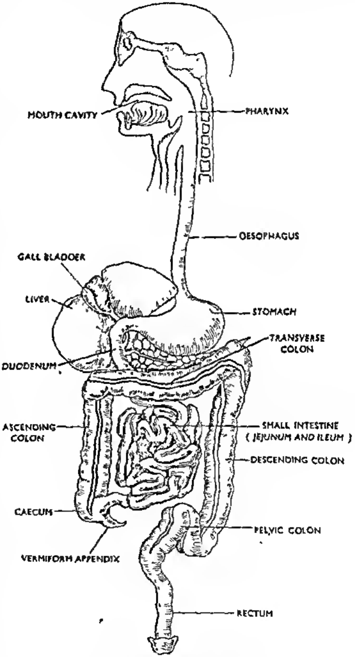


Fig. 669. The digestive system.

The evolution of the digestive system. In the unicellular organism like the *protozoa*, or in the other simpler forms of life such as the *bacteria* there is no digestive system. They also need food but the simplicity of their body mechanics does not require for the existence of a separate digestive system and they absorb food in solution from their body surface. In the higher forms like the *metazoa*, a multicellular organism, there develops a specialized cavity within the body, the *enteron* which is provided with only one opening which serves for both entrance of food and exit of food residue as for example the

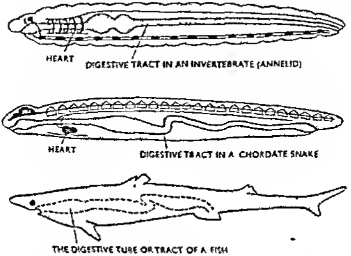


Fig. 670

Coelenterata. In the still higher forms, such as in the *Annelida*, there is further advancement in the development of the digestive tube; here the enteron is provided with two openings, one for the entrance of food and the other for the exit of food residue. In the *fishes*, there is further elaboration of the enteron. In addition to the mouth, the anterior part of the enteron provides openings to the exterior as gill slits in association with the formation of the gill arches. Moreover the cavity of the enteron, in addition to the formation of *pharynx* in which there are the gill arches and the gill slits, there develops reception chamber, the stomach, and a digestive chamber, the intestine, and the mouth cavity is endowed with teeth. In some vertebrates, such as the *tetrapoda*, further elaboration in the enteron is the formation of the oesophagus, tongue and the rectum. In higher mammals, such as in man, there is marked development of the intestines which can be divisible into large and small intestines. The small intestine can be divisible into duodenum, jejunum and ileum and the large intestine has developed enormously to form caecum, vermiform appendix, ascending colon, transverse colon, descending colon, pelvic colon, rectum and anal canal.

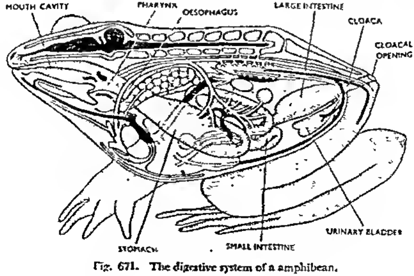


Fig. 671. The digestive system of a amphibean.

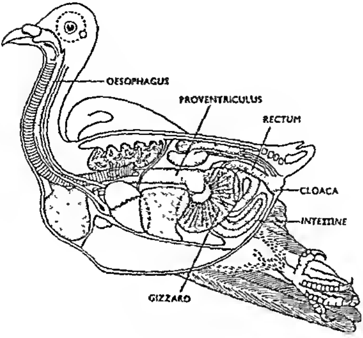


Fig. 672. The digestive system of a bird.

THE MOUTH AND THE LIPS

The **mouth** or the oral cavity consists of two parts, a *vestibule* and a mouth *cavity proper*. These two parts are separated from each other by the teeth, the alveolar processes and the gums. When the mouth is closed the two parts communicate with each other by a narrow space between the last molar teeth and the ramus of the mandible, and when it is open, by the space between the upper and lower teeth.

The **vestibule** is bounded, externally, by the lips and the cheeks, and internally, by the upper and lower teeth. It opens externally at the aperture of the mouth. The parotid duct opens into the vestibule of the mouth in the summit of a papilla opposite the upper second molar tooth.

The **lips** are soft movable structures which surround the oral aperture; they are two in number, upper and lower, and each has a free border and an attached border. On each side, the two lips meet at an angle called the *angle of the mouth.* The attached border of each lip, besides having a muscular slip of attachment to the bone (Incicivum labii superioris and inferioris), is fixed to the respective jaw by a median fold of mucus membrane called the *frenulum of the lips.* The free margin and the inner aspect of each lip are covered by the mucous membrane and consequently they are more transparent. Due to this transparency the underlying capillaries impart their reddish-pink colour to these parts of the lips. Externally the lips are covered by the skin. In between the skin and the mucous membrane there lie the voluntary muscular sphincter, the *orbicularis oris*, externally, and the submucosa containing the mucous glands internally. Thus structurally each lip consists of cutaneous, muscular, glandular and mucous layers from without inwards. The superior and the inferior labial branches of the facial artery anastomose with each other to form a complete arterial circle around the lips and are placed between the muscular and glandular layers. The arteries passing to the individual lip can be compressed by grasping the respective lip between the fingers. Thus haemorrhage from the lip can be controlled by compressing the same on either side by fingers.

The **cheek** consists of six layers and from without inwards they are the *skin, buccal pad of fat, buccopharyngeal fascia, buccinator muscle, molar glands* and the *mucous membrane.*

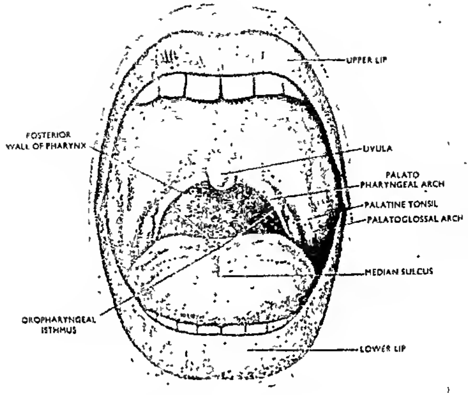


Fig. 673. The mouth cavity.

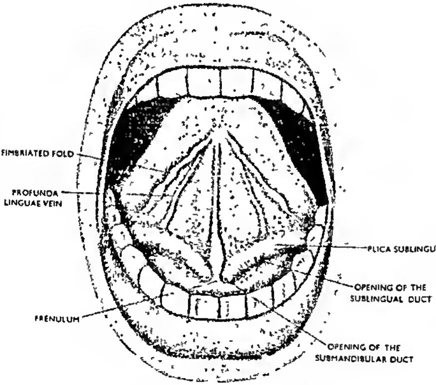


Fig. 674. The floor of the mouth cavity.

The **mouth cavity proper** has a floor and a roof and communicates posteriorly with the pharynx by the *Oro-pharyngeal isthmus* and through the pharynx it communicates with the nasal cavities as well. Anteriorly it communicates with the vestibule between the teeth, and with the exterior, through the oral aperture.

The *floor* of the mouth gives origin to the root of the tongue posteriorly, and anteriorly, on either side, it is formed by the sublingual region formed by the sublingual salivary glands and the mylohyoid, geniohyoid, genioglossus muscles and the anterior belly of the digastric muscle. Opposite the median plane the undersurface of the tongue is anchored to the floor of the mouth by a fold of mucous membrane known as the *frenulum of the tongue.* When the tongue is raised the lingual vein stands out blue on its either side. Lateral to the lingual vein on either side is a *fimbriated fold.* Opposite the root of the frenulum, on either side, the openings of the sub-mandibular ducts can be seen. Running backwards and laterally from it is a rounded ridge called the *plica sublingualis* which overlies the upper border of the sublingual salivary gland.

THE TEETH

Evolution of teeth. The presence of teeth is a vertebrate characteristic. In them the aquisition of teeth is a new feature which sharply differentiates the vertebrates from the invertebrates who do not possess any tooth, although some of them might have hard mouth appendages subserving the same functions as the teeth. In the vertebrates, with the progress of evolution, change in form and features of the teeth becomes well-defined and such dental features may acquire so much speciality that one group of the vertebrates may be sharply differentiated from the other by the inspection of the teeth alone.

The post primitive type of teeth is associated with the placoid scales scattered all over the surface of the body of the **celachians**, a kind of cartilaginous fish. Structurally these teeth are homologous with the teeth of the other higher forms of vertebrates.

In the **cyclostomata,** such as in the lampreys and in the hag fishes, the mouth is contained within the bottom of a suctorial disc, the *oral funnel,* which is surrounded by a number of papillae or the horny teeth. Surrounding the walls of the mouth cavity including the rasplike tongue there are a series of rows of sharply pointed horny teeth which are used for making a firm grip on the body of their prey for using their oral funnel as a suction cup.

In the **elasmobranchs,** another kind of fish, all the teeth are similar in form and they are not attached to the jaws but they develop in parallel rows in the mucous membrane of the mouth cavity. When a tooth is lost it is replaced by another which moves forward to take the place of the lost one. Such animals are said to be *homodont animals.*

In the **teleostean fishes** a further improvement in the elaboration of the teeth is the fixation of the base of each tooth to the underlying bone and reduction in their number.

In the **amphibians** the number of the teeth is further reduced towards the progress of evolution.

In some of the **reptiles,** such as the crocodiles, there is considerable advancement towards mammalian characteristics. In them, each tooth is provided with a separate socket, the number of the teeth is limited and they (teeth) are not similar in their physical form and instead, they are grouped into different forms subserving particular functions. Usually three types of teeth, such as incisors or cutters, canines or penetrators (daggers) and molars or grinders, can be identified. Thus the reptilean teeth are of *heterodont types* in which their physical forms vary according to the functions.

In the **mammals** the teeth are of *heterodont types* and the reptilean conditions are mostly repeated. In the mammals the number of teeth varies considerably, and both the size and number are reduced in the higher forms. In man the number is 16 in each jaw (2 incisors, 1 canine, 2 premolars and 3 molars) and their number and size may be reduced in more civilized races.

N.B. The birds have no teeth but their beak subserves the purpose of the both.

Classification of teeth. Teeth may be classified into deciduous, temporary or milk teeth and permanent teeth. The deciduous teeth are twenty in number—two incisors, one canine and two premolars on each half of alveolar arch. The deciduous or temporary teeth are replaced by permanent ones. The permanent teeth are thirty-two in number, two incisors, one canine, two premolars and three molars on each half of alveolar arch. Thus it shows that the molars are not preceded by deciduous teeth but they are permanent from the time of their eruption. The dental formula for the deciduous and permanent teeth is as follows:

Deciduous teeth	*Permanent teeth*
$\frac{2.1.2/2.1.2}{2.1.2/2.1.2}$	$\frac{2.1.2.3/2.1.2.3}{2.1.2.3/2.1.2.3}$

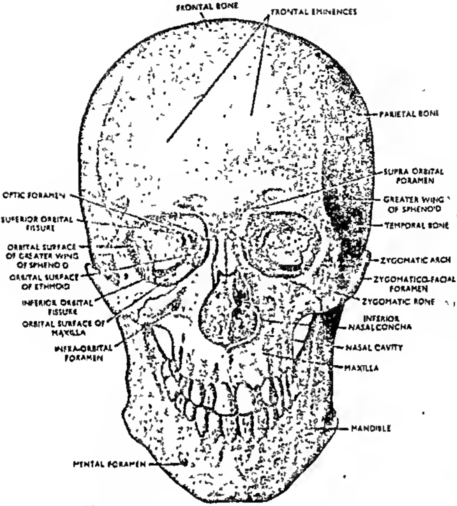


Fig. 675. The skull with the lower jaw. Seen from the front.

Time of eruption of deciduous teeth. At birth, the jaws are rigid bony bars lined by mucous membrane which are just suitable for grasping a nipple. Between sixth and ninth months the lower medial incisor first erupts out and this is followed by upper medial incisor, upper lateral incisors, lower lateral incisors, first premolars, canines and the second premolars and the whole process is completed by 24 months.

Time of eruption of permanent teeth. At sixth year, the permanent teeth begin to appear and it is the first molar that appears first. Because the first molars are the first permanent teeth which appear during the sixth year they are often called the *sixth year molars*.

Succeeding the first molars, the deciduous teeth are replaced by permanent ones in the following order: medial incisors, lateral incisors, first premolars, the second premolars and the canines. Next, the second molars erupt out during the twelfth year and the third molars begin to sprout out at about eighteenth year or even much later. Sometimes they fail to erupt at all.

Parts for examination of a tooth. Each tooth consists of a *root*, a *crown* and a *neck*. The portion buried within the jaw is called its root while the portion projecting beyond the gum is called the crown. The neck is the constricted portion situated at the junction between the two portions. At the apex of each root is a pin-point foramen known as the *apical foramen* for the transmission of vessels and nerves.

Each tooth consists of labial, lingual, proximal, distal and occlusional surfaces. The *labial surface* is directed towards the lips or cheek and the *lingual surface* towards the tongue. The opposed bilateral surfaces are called proximal or mesial and distal surfaces; the *proximal* or *mesial surface* is nearer to the central incisor while the *distal surface* being nearer the third molar. The surfaces of the teeth of the upper and the lower jaws which meet one another when the mouth is closed are called the *occlusional, masticatory* or *chewing surfaces.*

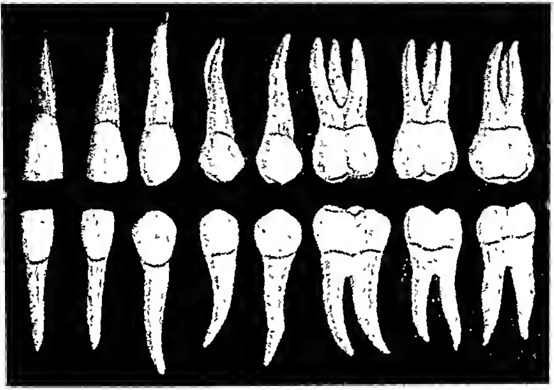


Fig. 676. The permanent teeth of the left upper and lower jaws.

Crowns. The crown of each human tooth consists of three tubercles two labial and one lingual. In case of the incisors the labial tubercles are fused together to form a cuting edge and the lingual tubercle is rudimentary. In the canines the labial tubercles are fused to form a single large cone and the lingual tubercle is well defined. In the premolars, the labial tubercles become cusp-like. The molars in general have two labial tubercles and a proximal lingual tubercle except those of the upper jaw. The molars of the upper jaw consists of two labial and two lingual tubercles (4 tubercles).

Roots. The roots of the incisors, canines, and premolars are single. The molars of the lower jaw have two roots, proximal and distal, while the upper molars have three roots, two smaller labial and one larger lingual.

Structure of tooth. Each tooth is composed of *enamel, cement, dentine* and *pulp*. The *enamel* is the white insensitive substance that covers the crown and is of ectodermal origin. The *cement* is bony and covers the roots of the teeth and is of mesodermal origin. The *dentine* is the yellowish basis of the tooth which is extremely sensitive and is surrounded by the enamel and the cement and contains a cavity within known as the *pulp cavity*.

Each tooth is contained in a conical bony socket and intervening between the root and the socket is a vascular membrane known as the *dental periosteum* (peri-

odontal membrane) which is continuous with the lamina propia of the gum and i attached both to the cement of the tooth and the walls of the socket.

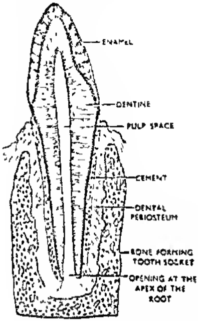


Fig 677. A section of a tooth showing its structure.

Microscopically the pulp tissue in the adul consists of gelatinous bosophile ground substanc of the nature of the mucoid tissue, a numbe of thin collaginous fibrils running in all direc tions, a few star-shaped cells, macrophages an a few lymphoid cells. The cells in close contac with the dentine are large, elongated and ar arranged like the epithelial cells. They ar called the *odontoblasts* which send out their pro toplasmic processes through the dentinal tubul of the dentine. It also contains blood vessel nerves and lymphatics.

Vessels of the teeth. The molars and the premolars of the upper-jaw are supplied b posterior superior dental branches of the maxi llary artery while the incisors and the canine are supplied by anterior superior dental branche from the infra-orbital artery. All the teeth of th lower jaw are supplied by the inferior dental hranch of the maxillary artery. The artery to the pulp enters it through the minute opening at the apex of each tooth.

The veins are corresponding to the arteries.

Lymphatics of the teeth. Lymphatics from the pulp drain into the sub-mandibular and deep cervical lymph nodes.

Nerves of the teeth. The upper molars and premolars are supplied by posterior superior dental branches of the maxillary nerve while the canines and the incisors are supplied by anterior superior dental branches of the infra-orbital nerves. The teeth of the lower jaw are supplied by the inferior dental branch of the mandibular nerve.

Development. The teeth are developed both from ectoderm and mesoderm. During the fifth week of foetal life, the buccal ectodermal cells form a continuous curved thickening known as the *dental lamina* along the edge of the future upper and lower jaws. Each dental lamina sinks into the underlying mesoderm and soon the epithelial cells show a symmetrically-arranged bud-like thickenings on each side which form the primodia of the enamel organ of the deciduous teeth. The dental lamina then extends beyond the last deciduous tooth germ and forms the primodia of the *enamel organ* of the permanent molars which are not preceded by the for-

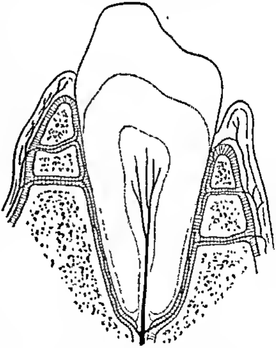


Fig. 678. A section of a tooth showing the distribution of the nerve. With kind permission from Prof. Hollinshead, Anatomy for the Surgeons, Vol. I, W. B. Saunder's Company, Philadelphia and London.

mation of the corresponding deciduous teeth. Each enamel organ then further sinks into the mesenchyme and subsequently becomes invaginated by the underlying mesodermal cells which have become condensed to form the primodium of the *dental papilla.*

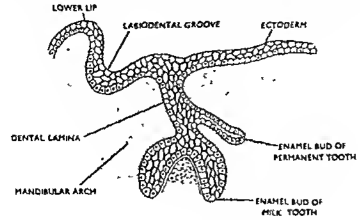


Fig. 679. The development of a tooth.

The enamel organ now differentiates into an outer epithelial layer and an inner ameloblastic layer which later on develops into enamel. Between these two layers is a cavity known as the *enamel sac* which is filled up by loosely arranged stellate reticulum. The cells of the dental papilla lying in contact with the ameloblast become arranged in a continuous odontoblastic layer and the dentine forms from the outer aspect of this layer. The ameloblast lay down successive layers of calcoglobulin which later on becomes hardened to form *enamel rods* lying on the outer aspect of dentine.

Between the tenth and the twelfth weeks of foetal life the remainder of the dental lamina forms the primodia of the enamel organ of the permanent teeth in the same way as in the deciduous teeth. The primodia of the permanent tooth germ lie on the lingual side of the corresponding deciduous tooth germ. The dental lamina then soon disappears after the formation of the primodia of the permanent tooth germ. The further development of the permanent teeth take place exactly in the same way as the deciduous teeth.

THE TONGUE

The tongue is a muscular organ which functions as an organ of taste, deglutition and speech and is situated in the floor of the mouth cavity.

It consists of a *root* which is anchored to the floor of the mouth, a *body* that projects from the root, an *apex* or *tip*, *superior* or *dorsal* and *inferior surfaces* and the *right* and *left borders.*

The **root** of the tongue is attached to the hyoid bone and the mandible and the **tip or apex** lies in contact with the incisor teeth. The **superior surface** or the **dorsum of the body** is convex from all sides and is divided into anterior two-thirds or oral part and posterior one-third or pharyngeal part by a 'V'-shaped sulcus called the *sulcus terminalis*. The limbs of the sulcus terminalis converge backwards from the palato-glossal arch to meet at a median pit, the *foramen caecum*. The sulcus terminalis intervenes between the oral and the pharyngeal parts of the tongue which differ from each other in many respects. The **inferior surface** lies in contact with the floor of the mouth and is connected with the same opposite the median plane by a fold of mucous membrane known as the *frenulum*. On either side of the frenulum the openings of the sub-mandibular duct can be easily seen.

Mucous membrane of the tongue. The mucous membrane covering the pharyngeal part of the tongue is devoid of any papillae but contains numerous nodules

of lymphoid tissue collectively called the *lingual tonsil.* The mucous membrane is continuous with the lingual surface of the epiglottis and opposite the median plane a fold of mucous membrane, the *glossoepiglottic fold* connects the dorsal surface of the tongue with the epiglottis; between it and the pharyngo-epiglottic fold is a deep depression called the *vallecula.* The mucous membrane covering the oral part of the tongue are pervaded with numerous papillae of distinctive appearance. The inferior aspect of the tongue opposite the median plane is connected with the floor of the mouth by the frenulum and lateral to the frenulum on each side is an indistinct fold called the *plica fimbriata.* In between the frenulum and the plica fimbriata the venae commitans hypoglossi profunda linguae can be seen shining through the mucous membrane. On either side of the tongue, opposite the region of the limbs of the sulcus terminalis, there are a series of mucous folds known as the *papillae foliatae.*

DIFFERENT PAPILLAE ON THE DORSUM OF THE ANTERIOR TWO-THIRDS OF THE TONGUE:

(1) **Filiform papillae.** They are arranged in 'V'-shaped rows and are scattered all over the dorsum of the tongue. They contain touch corpuscles.

Microscopically each filiform papilla consists of a central core of connective tissue which is arranged like the branches of a tree. The branching processes of the connective tissue core are surrounded by stratified epithelium which taper into pointed processes.

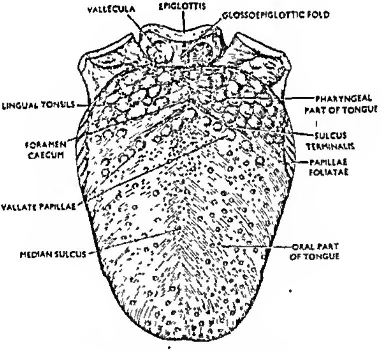


Fig. 680. The dorsum of the tongue.

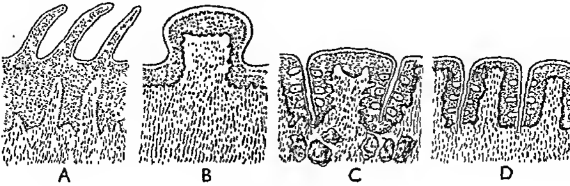
(2) **Fungiform papillae.** They are scattered singly among the filiform papillae in the region of the tip and margin of the tongue.

Microscopically each fungiform papilla presents a constricted stalk and a rounded and expanded, flattened top. Each has a central connective tissue core. These papillae are rich in blood vessels and therefore they appear to be red in colour.

(3) **Vallate papillae.** They are about 12 in number and are arranged in 'V'-shaped rows. They are large and circular and are present on the posterior part in front of the sulcus terminalis. They are so called because each of them is encircled by a trench-like furrow **(vallum).**

Microscopically each papilla consists of a connective tissue core which is surrounded by stratified epithelium which is comparatively smooth. The epithelial covering of each of its lateral wall contains many taste buds.

Associated with each vallate papilla there are some serous glands (Von Ebner's gland) which are deeply placed in the underlying muscle but their ducts open into the trench-like furrow surrounding each papilla.



A = Filiform papilla.
B = Fungiform papilla.
C = Vallate papilla.
D = Foliate papilla.
Fig. 681. The different papillae on the tongue.

(4) **Papillae simplicis.** They are scattered all over the dorsum of the tongue and are microscopic elevations of the corium.

Foliate papillae. These papillae are well developed in many animals in whom they form the main peripheral organ of taste. In man they are rudimentary. They are found on the lateral surface of the posterior part of the tongue and are arranged in pairs.

Glands in connection with tongue. Three types of glands are found in association with the tongue namely, mucous glands, serous glands and mixed type of glands.

Mucous glands are found over the posterior portion of the tongue, and the serous glands (Von Ebner's) in the region of the vallate papillae. The mixed type of glands (gland of Nuhn) are usually found on the under-surface of the tip of the tongue.

Difference between the anterior two-thirds and the posterior one-third of the tongue

	Anterior two-thirds	Posterior one-third
Developmentally	Develops partly from the tuberculum impar, a median elevation on the floor of the mouth and partly from both sides of the median plane from the ingrowing shelves of the mandibular arch.	Not bilateral in development; originates from the anterior part of a median bar, the *hypobranchial eminence* formed by the fusion of the second and the third arches.
Structurally	No submucous coat; consists of mucous membrane, tunica propria (fibrous storma) and the muscular coat; presence of different papillae in the mucous membrane.	Has a submucous coat; no papillae in the mucous membrane; the submucous coat presents numerous encapsulated lymphatic nodules collectively called the lingual

	Anterior two-thirds	Posterior one-third
Functionally	Concerned with salt, sonr and sweet tastes.	Concerned with bitter taste.
In nerve supply	Lingual nerve for general sensibility, chorda tympani for taste.	Glossopharyngeal nerve is the nerve of both the taste and general sensibility.
Topographically	The dorsal surface is directed upwards and lies in front of the sulcus terminalis; its inferior surface is attached to the floor of the mouth by the frenulum linguae which separates on each side the orifices of the sub-mandibular ducts.	The dorsal surface is directed backwards and lies behind the sulcus terminalis; it is attached to the epiglottis by the glossoepiglottic fold which separates two fossae, the vallecula, one on each side.

Fnnctions of the tongue:

(1) It is the main organ of taste.
(2) It helps in mastication by pushing the food in between the teeth.
(3) It helps in deglutition by forcing the bolus of food backwards through the fauces.
(4) It helps in articulation of speech.

Muscles of the tongue:

(1) *Extrinsic muscles:*
(a) Genioglossus.
(b) Hyoglossus.
(c) Palatoglossus.
(d) Chondroglossus.
(e) Styloglossus.

(2) *Intrinsic muscles:*
(a) Longitudinalis linguae superior.
(b) Longitudinalis linguae inferior.
(c) Transversus linguae.
(d) Verticalis linguae.

Extrinsic muscles of the tongue. Of the extrinsic muscles of the tongue genioglossus, hyoglossus and the styloglossus have already been described. The palatoglossus has been described along with the soft palate.

Chondroglossus. It is a part of the hyoglossus muscle and is separated from the same by the pharyngeal fibres of the genioglossus muscle. It takes its origin from the base of the lesser cornu of the hyoid bone and ascends upwards to be inserted into the intrinsic muscle of the tongue in between the fibres of the genioglossus and the hyoglossus.

Intrinsic mnscle of the tongue. *Longitudinalis linguae superior.* It consists of longitudinal set of fibres placed immediately beneath the mucous membrane of the dorsum of the tongue. It arises from the submucous layer and from the median septum and passes to the sides and the tip of the tongue. Some of its fibres are inserted to the mucous membrane.

Longitudinalis linguae inferior. It is a narrow band of muscle fibres beneath the mucous membrane on the inferior aspect of the tongue and extends from the root to the apex of the tongue. Anteriorly it blends with the fibres of the styloglossus and posteriorly some of its fibres are connected to the hyoid bone.

Transversus linguae. It is intermidiate in position and arises from the median fibrous septum and extends laterally to be inserted into the submucous layer at the sides of the tongue.

Verticalis linguae. It forms a band of fibres at the sides of the tongue and connects the dorsum with the inferior aspect of the tongue.

Vascular supply of the tongue. The lingual branch of the external carotid artery forms the main artery supply of the tongue. In addition, it gets some twigs from the tonsillar branch of the facial and ascending pharyngeal arteries. The veins of the tongue accompany the arteries and end in the internal jugular vein.

Nerve supply of the tongue. The nerves supplying the tongue consist of (1) motor and (2) sensory nerves.

(1) *Motor nerve.* Hypoglossal nerve is the motor nerve of the tongue which supplies all the muscles of the tongue except the palatoglossus which is supplied by accessory nerve through pharyngeal plexus.

(2) *Sensory nerves.* The sensory nerves supplying the tongue are of two types—nerve of general sensibility and nerve of special sense, that is, nerve of taste. The lingual nerve is the nerve of general sensibility (i.e., pain, heat, cold, touch, etc.) for the anterior two-thirds of the tongue and the chorda tympani nerve is the nerve of taste for the same area. The posterior one-third of the tongue is supplied by the glossopharyngeal nerve which is a nerve of taste as well as of general sensibility in this part. This part of the tongue (mainly vallecula of the tongue) also receives some sensory filaments from the internal laryngeal branch of the superior laryngeal nerve. For explanation of the different nerve supplies of the tongue, see its development.

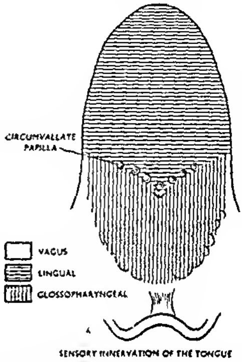


Fig. 682 The sensory innervation of the tongue. With kind permission from Prof. Hollinshed, Anatomy for the Surgeons, Vol. 1, W. B. Saunder's Company, Philadelphia and London.

Lymphatics of the tongue. The lymphatics of the tongue arrange in a plexiform network within the mucous membrane and the muscles of the tongue and both the sets of plexuses are continuous with each other.

The portion of the tongue in front of the papillae vallatae is drained by three sets of lymph vessels—apical, marginal and central, and the posterior portion of the tongue, i.e., the portion of the tongue lying behind the papillae vallatae, is drained by dorsal or basal sets of lymph vessels. Thus we see that four sets of lymph vessels—apical, marginal, central and dorsal or basal, drain the whole of the tongue and they are distributed in the following ways:

(*a*) **Apical.** These lymphatics drain the tip of the tongue and the region of the frenulum and descend downwards through the mylohyoid muscle to end in the following ways:
 (*i*) Some end in the submental lymph nodes and one of these vessels from the submental lymph nodes descend downwards over the hyoid bone and ends in the jugulo-omohyoid lymph nodes.
 (*ii*) Some end into the sub-mandibular lymph nodes.
 (*iii*) Some vessels pass deep to the sublingual salivary gland and then accompanying the ranine vein end into the jugulo-digastric lymph nodes. Some others descend downwards over the tendon of the digastric muscle and end in the jugulo-omohyoid lymph nodes.

(*b*) **Marginal lymph vessels.** They drain the sides or margins of the tongue and end in the following ways:
 (*i*) Some of the marginal lymph vessels descend downwards over the sub-

lingual salivary gland and pierce the mylohyoid muscle and end in the sub-mandibular lymph nodes.

(ii) Some pass deep to the sublingual salivary gland and after piercing the mylohyoid muscle end in the jugulo-digastric or jugulo-omohyoid lymph nodes.

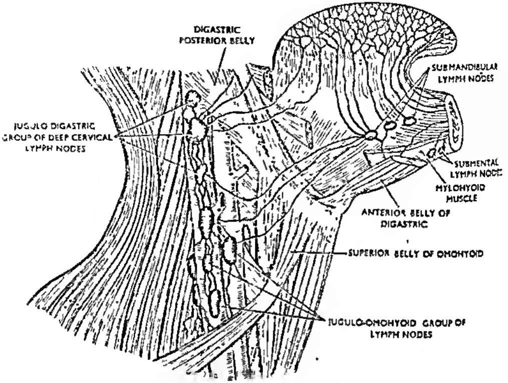


Fig. 683. The lymphatics of the tongue.

(c) **Central set of lymph vessels.** These are vessels which drain the area of the tongue on either side of the median raphe. They pass vertically downwards through the median plane between the two genioglossi muscles and then dicussate in the median plane to join with the deep cervical lymph nodes, especially the jugulo-digastric and jugulo-omohyoid lymph nodes. Some after piercing the mylohyoid muscle end in the sub-mandibular lymph nodes.

(d) **Dorsal or basal set of lymph vessels.** These vessels drain the posterior part of the tongue, that is, the area of the papillae vallatae and the area behind it. Opposite the median plane the lymph vessels of one side may pass to the other and all of them pierce the wall of the pharynx and then accompanying the external carotid artery end in the jugulo-digastric lymph nodes. One of the vessels may pass behind the hyoid bone and after piercing the hyo-thyroid membrane may end into the jugulo-omohyoid lymph node.

N.B. Some of the apical lymph vessels may cross each other under the frenulum of the tongue and the lymph vessels of one side may pass to the other side. The efferent vessels of the submental lymph glands close to the median plane pass partially to either side.

Movements or actions of the tongue. The main action of the intrinsic muscles is to alter the shape of the tongue whereas the extrinsic muscles are concerned with different other movements of the tongue and these are as follows:

(1) Protrusion of the tongue—Genioglossus of both sides.

(2) Retraction of the tongue—Styloglossus of both sides.
(3) Depression of the tongue—Hyoglossus of both sides.
(4) Elevation of the root of the tongue—Palatoglossus of both sides.

Development of the tongue. The anterior two-thirds of the tongue are developed *partly from the tuberculum impar*, a median elevation on the floor of the mouth and *partly from the ingrowing shelves of the first or mandibular arch from either side.* Thus it is evident that the anterior two-thirds of the tongue are mostly bilateral in origin and the bilateral lingual swellings fuse with each other and with the tuberculum impar opposite the median plane. The mandibular nerve being the nerve of the first or mandibular arch the epithelium of the anterior two-thirds of the tongue is supplied by the same nerve through its lingual branch. The tuberculum impar develops in between the second arches and receives its nerve supply from the nerve of the second arch (facial) and as the tuberculum impar fuses with the anterior two-thirds of the tongue the latter receives the chorda tympani nerve (from the facial).

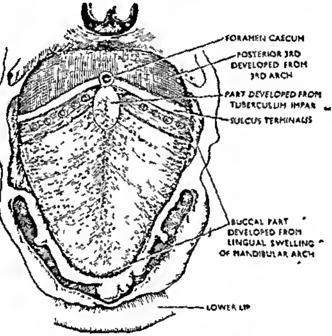


Fig. 684. The development of the tongue.

The posterior one-third of the tongue *develops from the anterior part of the hypobranchial eminence* formed by the fusion of the second and the third arches. It grows forwards with a 'V'-shaped anterior border which joins with the anterior two-thirds. The foramen caecum indicates the position of the thyroid diverticulum and is placed at the apex of the 'V'-shaped sulcus, the sulcus terminalis of the adult tongue. The glossopharyngeal nerve being the nerve of the third arch, the epithelium of the posterior one-third of the tongue is supplied by the same nerve because the mesoderm of the third arch grows and buries the mesoderm of the second arch.

The *muscles of the tongue* are derived from the *occipital myotome* which migrate into the tongue. The hypoglossal nerve being the nerve of the occipital myotomes the muscles of the tongue derive their nerve supply from the same source.

Histological structure. Structurally the tongue consists of interlacing bundles of striated muscle, a layer of mucous membrane and a submucous fibrous layer known as the *lamina propria* or the *corium.*

Muscular layer. This forms the deepest layer and consists of interlacing bundles of striated muscle fibres which run in three planes and intersect one another at right angle.

The submucous layer. There is no loose submucous layer over the dorsum of the tongue. However a loose submucous layer is present over the under surface of the tongue. The lamina propria or the corium of the mucous membrane is a dense feltwork of connective tissue consisting of white collagenous fibres and a few elastic fibres. Over the dorsum of the tongue the mucous membrane and the corium being tightly adherent to the underlying muscle mass there is no loose submucous layer as is found elsewhere. In this situation the lamina propria of the mucous membrane is fused with the interstitial connective tissue of the muscle. The blood vessels, nerves and lymphatics form intricate large plexuses in this layer and the different glands of the tongue are found to be scattered in this layer.

Mucous membrane. The mucous membrane overlies the corium or the lamina propria and is lined by stratified epithelium. Over the anterior two-thirds of the tongue it contains different types of the papillae which have already been described and over the posterior one-third it contains the *lingual tonsils* consisting of a large number of lymphoid follicles. Each lymphoid follicle is a rounded body which causes elevation over the tongue. Each has a central opening which opens into a dilated recess and surrounding this recess are found a number of nodules of lymphoid tissue each of which receives a fibrous investment from the corium.

Taste buds. The taste buds are the gustatory or taste organs which are specialised neuro-epithelial end-organs for taste and are distributed in the tongue and in the neighbouring areas.

Structure. They are flask-shaped bodies, each having a base and an apex. The base is attached to a basement membrane over the corium of the tongue while the apex projects towards the free surface. Opposite each taste bud, the covering surface epithelium is pierced by a small opening known as the outer taste pore or the gustatory pore. Each taste bud is associated with a filament of nerve of taste from the sub-epithelial nerve plexus.

Each taste bud consists of two types of cells, *supporting cells* and *neuro-epithelial taste cells* or *gustatory cells*. The supporting cells are spindle-shaped and their ends surround a small opening known as the *inner taste pore* which leads into a small pit-like cavity. The neuroepithelial taste cells are rod-shapeed cells baving a central nucleus and are found to be placed between the supporting cells. From the free end of each cell a short taste hair is found to project through the inner and outer taste pores.

Four kinds of basic tastes namely, salt, sugar, sour and bitter are recognised and the taste buds are the receptors for them. Though carrying different types of taste sensation no structural peculiarities bave been identified in the taste buds.

Distribution:

(1) They are abundantly present around the vallate papillae and a few around other papilla.
(2) Along the sides of the tongue.
(3) Over the mucous folds forming the papillae foliatae.
(4) Over the lingual surface of the soft palate.
(5) Posterior surface of the epiglottis.
(6) Posterior wall of the pharynx.

THE SOFT PALATE

The soft palate is a movable curtain which projects downwards and backwards into the pharynx and forms an incomplete septum between the mouth and the pharynx. It helps to shut off the nasal part of the pharynx from the part below during deglutition. Anteriorly it is attached to the posterior margin of the hard palate. On each side it is connected with the pharynx by the palato-pharyngeal arches. Posteriorly it is free and from the middle of its posterior margin a conical process termed the *uvula*, projects downwards. The upper surface of the soft palate

is convex and is continuous with the floor of the nasal cavity. Its lower surface is concave. Along its median plane an elevated smooth ridge may be found, indicating the line of fusion. Around the free posterior border the two surfaces of the soft palate are continuous with each other.

The soft palate consists of a double folds of mucous membrane which contains the following structures in between its two layers.

(A) *Palatal muscles:*
 (1) Two levator palatini.
 (2) Two tensor palatini.
 (3) Two glossopalatini (palatoglossus).
 (4) Two pharyngopalatini (palato-pharyngeus).
 (5) The musculus uvulae.

(B) *Palatal aponeurosis.*

(C) *Palatal glands.*

(D) *Arteries:*
 (1) Ascending palatine from facial.
 (2) Palatine branch from ascending pharyngeal.
 (3) Twigs from the lesser palatine branch of the descending palatine branch of the maxillary artery.
 (4) Twigs from the dorsal branch of the lingual artery.

(E) *Nerves:*
 (1) Greater and lesser palatine from the sphenopalatine ganglion.
 (2) Branches from the pharyngeal plexus.

Nerve sopply of the soft palate. *Motor supply.* All the muscles of the soft palate are supplied by the accessory nerve through the pharyngeal plexus (vagus) except the tensor palati muscle which is supplied by a branch from the mandibular nerve through the otic ganglion (because it is derived from the mandibular arch, the nerve of which is the mandibular nerve).

The glands and blood vessels of the soft palate receive visceral efferent (chiefly secretory) fibres (postganglionic) from the sphenopalatine ganglion through the small palatine nerves. The preganglionic fibres are derived from the superior salivary nucleus and join with the pars intermedia of the facial nerve (sensory root) and pass through the greater superficial petrosal nerve to the sphenopalatine ganglion —(Morris).

Sensory supply. The greater palatine and the glossopharyngeal nerves are the nerves of general sensibility for the soft palate. The visceral afferent fibres from the soft palate pass through the lesser or small palatine nerve. These fibres form the peripheral processes of the cells of the geniculate ganglion.

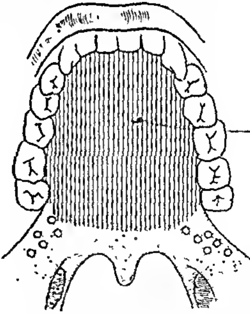


Fig. 685. The sensory supply of the hard and the soft palate.

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Levator veli palati. *Levator palati.* It is a rounded muscle which arises from the inferior surface of the petrous portion of the temporal bone in front of the external opening of the carotid canal and from the medial lamina of the cartilaginous part of the auditory (pharyngo-tympanic) tube. After its origin it passes through

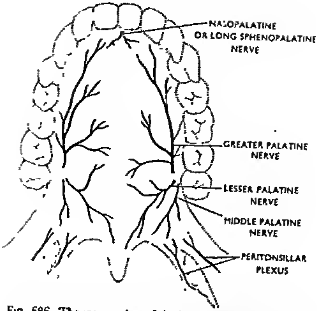

Fig. 686. The innervation of the hard and the soft palate.
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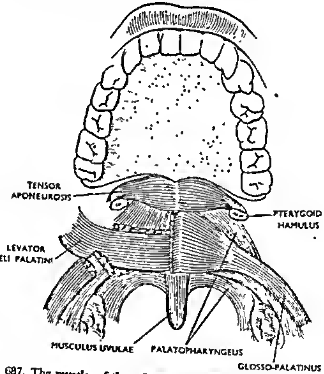


Fig. 687. The muscles of the soft palate. With kind permission from Prof. W. H. Hollinshead; Anatomy for the Surgeons, Vol. I, W.B. Saunder's Company; Philadelphia and London.

the gap between the base of the skull and the upper concave margin of the superior constrictor muscle of the pharynx (sinus of Morgangni) and reaches the soft palate and after being spread over the palatal aponeurosis it becomes blended with the fellow of its opposite side.

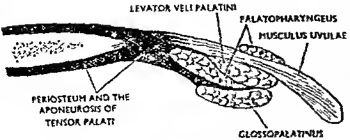


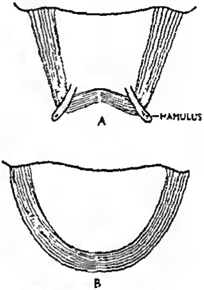
Fig. 688. Diagram of the apoueuroticomuscular structure of the soft palate, in longitudinal section. With kind permission from Prof. Hollinshead, Anatomy for the Surgeons, Vol. I, Paul B. Hoeber, INC.

Actions. It elevates the snft palate.

Tensor veli palati (tensor palati). It is triangular in form and arises from the scaphoid fossa nf the pterygnid process, from the lamina of the cartilaginous portinn of the auditory (pharyngo-tympanic) tube and from the roedial aspect nf the sphenoidal spine. It forms a narrow tendnn which hooks round the pterygoid hamulus and by passing above the upper border nf the superior *constrictor* muscle nf the *pharynx* it reaches the soft palate where it is inserted intn the palatal aponeurosis and into the inferinr surface of the horizontal plate nf the palatine bone behind the palatine erest.

It lies against the lateral surface of the medial pterygoid plate and its lateral aspect is intimately related to the mandibular nerve, ntic ganglinn and the middle meningeal artery.

Actions. Acting alone it draws the soft palate to the same side. Acting together it depresses the soft palate.



A=Pull by tensor palati.
B=Pull by levator palati.

Fig. 689. The actions of levator and tensor palati muscles. With kind permission from Prof. Hollinshead, Ph. D.; Anatomy for the Surgeons, Vol. I, Paul B. Hoeber, INC.

Palatoglossus. It arises from the upper surface of the palatal aponeurosis and is continuous with the fellnw of its opposite side in the median plane and descending downwards and laterally it blends with the sides of the tnngue being contained within the palatoglossal arch.

Actions. It depresses the sides of the soft palate and draws the tongue postero-superinrly. Acting with the tongue it closes the oropharyngeal isthmus.

Palatnpharyngeus It is contained within the palatopharyngeal arch and consists of anterior and posterior layers nf muscle fibres, and the cartilaginous portion of the auditory (pharyntn-tympanic) tube intervenes between the two layers. The *anterior layer* arises from the posterinr border nf the hard palate and the *posterior layer* arises from the palatal aponeurosis npposite the posterior border nf the soft palate and npposite the median palne it becomes enntinuous with the fellow nf its opposite side. At the posterolateral border nf the soft palate the two layers unite, and descending downwards and laterally, some nf its fibres are inserted into the posterior border of the thyroid cartilage, some blending with the wall of the pharynx and the rest blend with the fellow its opposite side.

Actions. Acting singly it elevates the pharynx on the same side and acting together they approximate the palatopharyngeal arches.

Musculus uvulae. It arises from the posterinr nasal spine nf the palatine bone and from the palatal aponeurosis and is inserted intn the submucous tissue nf the uvulae.

Actions. It elevates and shortens the uvula.

SALIVARY GLANDS

The viscous, colourless, opalescent, liquid discharge of the mouth cavity is known as the *Saliva*. The saliva consists of water, mucin, some protein, the enzyme ptyalin, mineral salts and some disquamated epithelial cells and the salivary corpuscles.

Mucous cells secrete mucin, the serous or albuminous cells secrete albuminous watery fluid which lacks in mucin but rich in salt, proteins and ptyalin. The mixed type of glands have both types of secretion. It is a collective discharge from various secretary glands located both within and outside the mouth cavity and these glands which produce the saliva are known as the *salivary glands*. There are numerous salivary glands of which some are small and are confined to the mucous and submucous coats of the mouth cavity while others are large glands which are located outside the mouth cavity and convey their secretions through their ducts. The smaller glands of the mouth cavity are seemed to secrete continuously to keep the oral mucous membrane moist. There are three pairs of larger glands namely *parotid*, *sub-mandibular* and *sublingual*, which constitute the salivary glands proper. In contrast to the smaller salivary glands of the mouth cavity, which pour out their secretions continuously, the larger salivary glands pour out their secretion in response to mechanical, thermal, chemical, and psychic or gustatory stimuli only. Structurally the salivary glands consists of either serous, mucous or mixed types of cells. Thus the salivary glands may be classified as under:

Salivary glands

- According to location of the opening ducts in the mouth
  - In the vestibule of the mouth
    - (i) Parotid gland.
    - (ii) Buccal glands.
    - (iii) Labial glands.
  - Floor of the mouth cavity
    - (i) Sub-mandibular gland.
    - (ii) Sublingual gland.
    - (iii) Some submucous and mucous glands.
  - Over the tongue
    - (i) Anterior lingual gland or gland of Nuhn or Blandfunder over the apex of the tongue at the side of the median plane.
    - (ii) Posterior lingual glands:
      - (a) some serous glands (glands of Von Ebner) which open in the gutter around the vallate papillae.
      - (b) some mucous glands which open near the root of the tongue.
  - Over the palate
    - (i) Glands of the palate.
- According to cell types
  - Serous or albuminous
  - Mucous
  - Mixed

Parotid gland. The parotid gland is the largest of the salivary glands and forms an irregular lobulated mass which lies below the external auditory meatus and fills up a hollowed out space, the parotid mould, between the ramus of the mandible in front and the mastoid process of the temporal bone and the sternocleidomastoid muscle behind.

Structures forming the parotid mould. Anteriorly, it is formed by the posterior part of the ramus of the mandible and the muscles inserted to it, that is, the medial pterygoid and the masseter. *Posteriorly*, it is formed by the anterior border of the sternocleidomastoid and the mastoid process. *Superiorly*, the anterior and the posterior walls converge being separated by a cleft that intervenes between the capsular ligament in front and the bony external auditory meatus behind. *Inferiorly*, the mould is limited

Natural constrictions. It is narrowest at its commencement opposite the level of the lower border of the sixth cervical vertabra, It is also constricted opposite the level of the lower border of the fourth thoracic vertebra where it is crossed by the arch of the aorta; it may also be constricted opposite the level of the fifth thoracic vertebra where it is crossed by the left bronchus. It also presents another constriction opposite level of the lower border of the tenth thoracic vertebra where it passes through the oesophageal opening in the diaphragm.

For descriptive purposes and according to the situation, the oesophagus has been divided into cervical, thoracic and abdominal parts.

Relations—**Cervical part.**

Anteriorly:

(1) Trachea throughout its course in the neck.
(2) Lobes of the thyroid gland at the lower part of the neck.
(3) The recurrent laryngeal nerves, one on each side, ascend in the groove between the trachea and oesophagus.

Posteriorly:

(1) Vertebral column and longus cervicis muscle from which it is separated by the prevertebral layer of the deep cervical fascia.

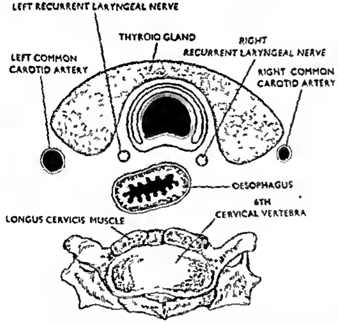


Fig. 697. The relations of the oesophagus opposite the level of the sixth cervical vertebra as seen in a transverse section.

Laterally:

(1) Common carotid artery.
(2) Lateral lobe of the thyroid gland.

Relations—**Thoracic part.**

Anteriorly: From above to downwards.

(1) Trachea throughout the upper part of the superior mediastinum only and in the lower part of the superior mediastinum, it separates the oesophagus from the arch of the aorta.
(2) Left bronchus.

(3) Pericardium containing the heart.
(4) Diaphragm.
(5) The left vagus lies in intimate contact with the oesophagus below the root of the lung.

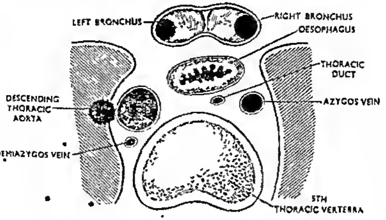


Fig 698. The relations of the oesophagus opposite the level of the upper border of the fifth thoracic vertebra as seen in a transverse section.

Posteriorly:

(1) Vertebral column throughout the entire extent.
(2) Longus cervicis muscle (in the superior mediastinum only).
(3) Right posterior or aortic intercostal arteries (in the posterior mediastinum only).
(4) Thoracic duct (throughout the entire extent of the posterior mediastinum).
(5) Axygos and hemiazygos veins (in the posterior mediastinum only).

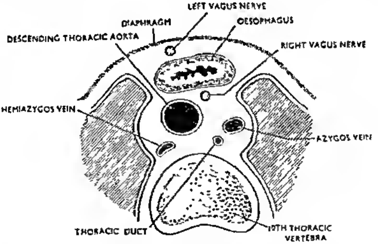


Fig. 699. The relations of the oesophagus opposite the tenth thoracic vertebra as seen in a transverse section.

(6) Terminal portion of the descending thoracic aorta (only for a small portion immediately above the diaphragm).
(7) Right vagus nerve (lies in contact with the oesophagus below the root of the lung).

by the posterior belly of the digastric. The *deep part* or *the bottom of the mould* is formed by the styloid process with the styloid group of muscles which separate it from the internal carotid artery, internal jugular vein and the last four cranial nerves.

Capsules. Each gland possesses a true and a false capsule. The true capsule is formed by the condensed mass of fibroareolar tissue whereas the false capsule is derived from the deep cervical fascia.

Parts for examination. The gland is roughly *pyramidal in shape* and has got a superior, a superficial, a posteromedial and an anteomedial surface and a blunt lower extremity. The gland gives out two and sometimes three processes (a) *retromandibular process* projecting into the inner aspect of the ramus of the mandible, (b) the *facial process* projecting on to the face over the masseter muscle and (c) the *accessory portion* lying between the parotid gland and the zygomatic arch.

Superior surface. This represents the upper pole of the gland and is in relation with the external auditory meatus and the posterior part of the mandibular joint and the auriculotemporal nerve which comes out from the substance of the gland in this situation and winds round the neck of the mandible.

Antero-medial surface. This surface overlaps the posterior part of the masseter muscle and the ramus of the mandible and projects inwards to come into relation with the medial ptergoid muscle. The facial branches of the facial nerve emerges on to the face from the anterior part of this surface.

Postero-medial surface. It is moulded on the mastoid process, the sternomastoid, the posterior belly of the digastric and the styloid group of muscles (stylohyoid, styloglossus and stylopharyngeus muscle). The external carotid artery grooves this surface before entering into the substance of the gland. The internal carotid artery and the internal jugular vein and the last four cranial nerves are separated from this surface by the styloid process and the styloid group of muscles.

The blunt lower extremity is in contact with the stylo-mandibular ligament and the posterior belly of the digastric muscle.

Structures within the parotid gland:

(1) *Superficial plane:*

(*a*) Lymphatic glands.
(*b*) Great auricular nerve.
(*c*) Facial nerve and its branches.

(2) *Intermediate plane:*

(*a*) Retromandibular (posterior facial) vein.
(*b*) (Internal) Maxillary vein.
(*c*) Posterior auricular vein.
(*d*) Commencement of the external jugular vein.

(3) *Deep plane:*

(*a*) External carotid artery.
(*b*) Transverse facial artery.
(*c*) Posterior auricular artery.
(*d*) Superficial temporal artery.
(*e*) Internal maxillary artery.

Structures that radiate from the peripheral margins of the parotid gland. Superiorly the superficial temporal artery crosses the posterior root of the zygoma to reach the scalp. The auriculo-temporal nerve lies behind it and the temporal branch of the fascial nerve lies in front of it and cross the zygoma'ic arch. Anteriorly the zygomatic and the upper buccal branches of the facial nerve, the transverse facial branch of the superficial temporal artery cross the masseter muscle and lie above the parotid duct. The lower buccal and the mandibular branches of the facial nerve cross the masseter muscle below the parotid duct. The cervical branch of the facial nerve enters the neck below and behind the angle of the mandible. The posterior auricular artery and the posterior auricular branch of the facial nerve run upwards aod backwards from its posterior part and cross the mastoid process of the temporal bone.

Vascular supply. The arteries supplying the gland are derived from the external carotid artery and from the branches given out by that artery in the substance of the gland (Superficial temporal and Maxillary). Veins drain into the external jugular vein.

Nerve supply. It is supplied by the glossopharyngeal nerve (via the tympanic branch of the glossopharyngeal nerve, tympanic plexus, lesser superficial petrosal, otic ganglion and the auriculo-temporal nerves), and by the sympathetic plexus of

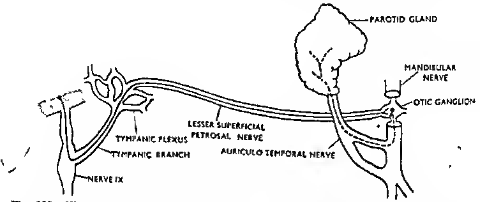


Fig. 600. The secretomotor supply of the parotid gland. With kind permission from Prof. Hollinshead: Anatomy for the Surgeons, Vol. I, Paul B. Hoeber, INC.

nerves accompanying the external carotid artery. The glossopharyngeal nerve supplies *secretomotor* fibres while the sympathetics supply the *vaso-constrictor* fibres to the gland.

Lymphatics. Three sets of lymph nodes are associated with the parotid gland. The lymph nodes *superficial* and deep to the parotid fascia drain the scalp, auricle and the eye lid and their efferents end in the upper deep cervical lymph nodes. Lymph nodes within the parotid gland drain the external auditory meatus, tympanum, soft palate and the deep part of the cheek in addition to the parotid gland and their efferents terminate in the deep cervical lymph nodes.

Development. The parotid gland develops as a diverticulum of the buccal ectoderm which runs dorso-laterally superficial to the branches of the facial nerve. Subsequently the expanded dorsal portion of the diverticulum gives out deep processes which pass inwards between the branches of the facial nerve and become fused together and thus the facial nerve becomes entangled within its substance. Thus developmentally the parotid gland may be subdivided into superficial and deep portions in between which the facial nerve intervenes. The narrower tubular portion of the buccal ectoderm forms the parotid duct.

Parotid duct. It is the excretory duct of the parotid gland and carries the salivary secretions from the gland to the mouth. It is about 5 cm. long and begins by numerous branches from the anterior part of the gland. It is sometimes joined by the accessory parotid duct when that gland exist. From its origin it passes transversely forwards across the masseter muscle and reaching the anterior border of that muscle it pierces through the sucktorial pad of fat, the buccinator muscle with it's fasciae and then it runs for a short distance between the muscle and the mucous membrane of the mouth and finally ends by opening into the summit of a papilla opposite the upper second molar tooth in the vestibule of the mouth. It is related above to the accessory portion of the gland, the upper buccal branch of the facial nerve and the transverse facial branch of the superficial temporal artery. Below it is related to the lower buccal nerve.

Sub-mandibular gland. The sub-mandibular gland is one of the salivary glands and is about the size of a walnut. It is enveloped by a sheath from the deep

cervical fascia and occupies the anterior part of the digastric triangle and is limited behind by the stylo-mandibular ligament, anteriorly by the anterior belly of the digastric, below by the intermediate tendon of the digastric and the stylohyoid muscle and above by the ramus of the mandible.

Each gland consists of a superficial and a deep portioo and the two parts are continuous with each other at the posterior border of the mylohyoid muscle.

The *superficial part of the gland* possesses an *inferior*, a *lateral* and a *medial surface*. The *inferior surface* is covered by skin, superficial fascia, platysma and the deep fascia. The (anterior) facial vein and the cervical branch from the facial nerve cross this surface. The *lateral surface* is in relation with the mylohyoid, hyoglossus, styloglossus, stylohyoid and the posterior belly of the digastric muscles. The mylohyoid vessels and nerve pass forwards between the gland and the mylohyoid muscle. The facial (external maxillary) artery grooves the posterior and superior part of the gland.

The *deep part of the gland* lies in between the hyoglossus and styloglossus medially and the mylohyoid laterally. It extends forwards as far as the sublingual gland. It is in relation with the lingual nerve and the sub-mandibular galglion above and the hypoglossal nerve and its venae commitaotes below.

Artery supply. The arteries supplying the sub-mandibular gland are derived from the lingual and facial branches of the external carotid artery.

Nerve supply. It is supplied by branches from the sub-mandibular ganglion through which it receives fibres from the chorda tympani (secreto-motor fibre) and lingual, it is also supplied by sympathetic nerves.

Sub-mandibular duct. The sub-mandibular duct is as long as the parotid duct (5 cm.) but its walls are thinner. It is formed by the union of several smaller ducts and emerges from the middle of the deep surface of the superficial part of the gland. It runs forwards beneath the deep part of the gland between the mylohyoid and the hyoglossus muscles. Then it runs further forwards between the medial surface of the sublingual gland and the genioglossus muscle and finally it ends by opening into the summit of the sublingual papilla situated at the floor of the mouth on the side of the frenulum of the tongue.

In its course over the hyoglossus muscle it lies below the lingual nerve and above the hypoglossal nerve; at the anterior border of the hyoglossus muscle opposite the level of the second molar tooth the lingual nerve crosses the duct superficially from above downwards; more anteriorly while the sub-mandibular duct lies under cover of the sublingual gland, the lingual nerve crosses deep to it from below upwards. Thus the lingual nerve crosses the sub-mandibular duct twice in its course to the tongue.

Sublingual salivary gland. The sublingual gland lies in the sublingual fossa of the mandible on either side of the symphysis menti and lies in the floor of the mouth under cover of the mucous membrane on each side of the frenulum linguae. It is the smallest of the three salivary glands and is about 1 dr. in weight.

Relations. *Anteriorly* it meets the fellow of its opposite side in the median plane. Posteriorly it is related to the deep part of the sub-mandibular gland. Laterally it is related to the sublingual fossa of the mandible. Medially it is related to the genioglossus muscle and intervening between the two are the lingual nerve and sub-mandibular duct.

Ducts of the sublingual gland. The ducts of the sublingual gland are numerous and vary between eight and twenty in oumber. Some of the smaller sublingual ducts open into the sublingual fold in the floor of the mouth on either side of the frenulum linguae. Some open into the sub-maodibular duct and others unite to from the *principal sublingual duct* which opens in the floor of the sub-mandibular duct.

Vascular supply. It is supplied by sublingual and the submental arteries.

Nerve supply. It is supplied by the lingual (sensory) and the chorda tympani nerves (secretomotor) and sympathetic fibres through sub-mandibular ganglion.

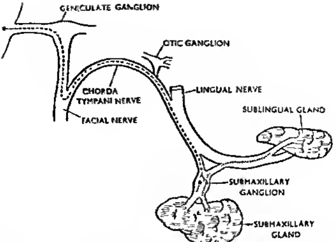


Fig. 691. The innervation of the sub-mandibular and sublingual salivary glands. With kind permission from Prof. Hollinshead, Ph. D.; Anatomy for the Surgeons, Vol. I, Paul B. Hoeber, INC.

Development of sub-mandibular and sublingual glands. The sub-mandibular gland appears as solid outgrowths of the buccal epithelium from the alveo-lingual groove at about the fifth week of embryonic life. The sublingual gland appears similarly as several smaller outgrowths at about the ninth week of intrauterine life.

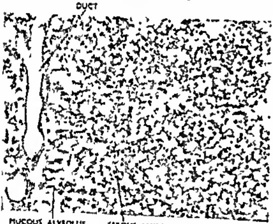


Fig. 692. Microphotograph of a section of the sub-mandibular salivary gland.

Structure of Salivary glands. The larger salivary glands are subdivided into several lobules by areolar tissue and from each lobule a duct emerges. The epithelium of the duct is columnar in type. In the parotid gland the alveolar cells are mostly serous. In the sublingual and sub-mandibular glands the alveolar cells are of mixed types, that is, they contain both serous and mucous cells. The alveolar cells of the sublingual gland are mostly mucous. In both the sublingual and sub-mandibular glands some of the alveoli are lined superficially by larger clear mucous cells whereas the smaller granular serous cells are in contact with the basement membrane deep to the mucous cells and are arranged in cresentic masses which are known as crescents or demilunes of Gianuzzi.

THE PHARYNX

The pharynx is that portion of the alimentary tract which extends from the base of the skull to the lower border of cricoid cartilage where it is continuous with the oesophagus. It is five inches long and has its transverse diameter greater than its antero-posterior diameter.

The *widest part* of the pharynx corresponds to the level of the hyoid bone while its *narrowest part* is at the oesophageal orifice.

Attachments of the pharynx. The pharynx gains its attachments by means of its pharyngobasilar fascia or the pharyngeal aponeurosis and by its muscles.

Cranially it is attached to the pharyngeal tubercle and the adjoining area on the basilar part of the occipital bone, petrous part of the temporal bone and to the auditory tube. *Ventrally* it is attached to the posterior margins of the medial pterygoid plate of the pterygoid process of the sphenoid bone and the pterygomandibular ligament, to the posterior end of the mylohyoid line of the mandible, sides of the tongue, hyoid bone and to the thyroid and cricoid cartilages.

Relations. It is bounded *posteriorly* by the buccopharyngeal fascia which separates it from the prevertebral layer of the deep cervical fascia, prevertebral muscles (longus cervicis and longus capitis muscles) and the anterior surface of the upper six cervical vertebrae. *Anteriorly* it is bounded by the nasal cavity, mouth and the larynx in order from above downwards. It communicates with these cavities by the chaonae, oropharyngeal isthmus, and the glottidis respectively. The *roof* is formed by the basilar part of the occipital and the body of the sphenoid bone. *Laterally* its upper part is related with the origin of the medial pterygoid muscle, the styloid process with its muscles (stylohyoid, styloglossus and stylopharyngeus), and the glossopharyngeal and hypoglossal nerves and the ascending pharyngeal artery and the ascending palatine and the tonsillar branches of the facial artery. Its lower part, that is, the laryngo-pharynx, is related laterally with the carotid sheath, upper part of the lateral lobe of the thyroid gland, superior thyroid artery and the inter·al laryngeal nerve.

The pharynx is divided into three compartments and they are as follows:

(1) **Nasal part of the pharynx or naso-pharynx.** The nasal part of the pharynx begins from the level of the base of the skull to the level of the soft palate and functionally belongs to the respiratory system along with the nasal cavities.

The nasopharynx consists of a roof, a floor, anterior, posterior and two lateral walls.

The **roof** is continuous posteriorly with the posterior wall forming a continuous arched wall. Superiorly it is attached to the basioccipital and the basisphenoid bones and extends from the pharyngeal tubercle (on the former bone) behind to the base of the nasal septum in front. Laterally it extends as far as the carotid canal in the petrous part of the temporal bone.

The mucous membrane of the roof together with the adjoining posterior wall are thrown into irregular folds which are studded with much lymphoid tissue, particularly in the children. This area (roof) of the nosopharynx characterised by the presence of much lymphoid tissue is known as the *pharyngeal tonsil* (Adenoids).

The **floor** of the nasopharynx is formed by the pharyngeal surface of the soft palate which falls short to reach the posterior wall of the naso-pharynx. Thus a space is left between the soft palate and the posterior pharyngeal wall which constitutes the *naso-pharyngeal* or the *pharyngeal isthmus*. It is bounded anteriorly by the uvula and the soft palate and laterally by the palatopharyngeal arches. Posteriorly it is bounded by that portion of the posterior pharyngeal wall where the palatopharyngeal arches from the sides gradually slope backwards and downwards to become almost continuous with each other so as to produce a fold of mucous membrane (the fold of Passavant), particularly during phonation and deglutition.

The **anterior wall** is open and is occupied by the two posterior nasal apertures.

The **posterior wall** is continuous with the roof and extends from middle of basioccipital bone to the lower border of the anterior arch of the atlas. At the junction of the posterior wall and the roof there may, occasionally, be found a blind median sac or recess known as the *pharyngeal bursa*. The paryngeal bursa represents the line of fusion between the tip of the notochord and entoderm of the foregut.

The **lateral wall** entends from the base of the skull to the level of the soft palate. It's cavity remains unchanged under all conditions and forms the widest part of the pharynx opposite the base of the skull. Each lateral wall presents a wide, slit-like lateral extension at its cranial end known as the *pharyngeal recess* (fossa of Rosenmuller). Antero-inferior to the pharyngeal recess is the opening of the auditory tube. Posteriorly this opening is bounded by a triangular elevation,

the *tubal elevation* formed by the pharyngeal end of the auditory (pharyngo-tympanic) tube.

(2) **Oral part of pharynx.** The oral part of the pharynx lies opposite the level of the second to the fourth cervical vertebrae. Superiorly it is continuous with the naso-pharynx through the pharyngeal isthmus and inferiorly it is continuous with the laryngo-pharynx. It consists of an anterior, a posterior and two lateral walls.

The **anterior wall** is deficient in its cranial part and presents the opening of communication with the oral cavity known as the *faucial isthmus* or the *oro-pharyngeal isthmus.* The faucial isthmus is bounded on either side by the palatoglossal arches, superiorly, by the uvula and the posterior margin of the soft palate, and inferiorly, by the dorsum of the tongue in the region of the sulcus terminalis. Caudal to the oro-pharyngeal isthmus the onterior wall of the oral part of the pharynx is formed by the root of the tongue together with its valleculae.

The **posterior wall** of the oro-pharynx corresponds to that part of the pharynx which is visible through the faucial isthmus and lies opposite the second to the fourth cervical vertebrae.

Each **lateral wall** of the oro-pharynx presents the *sinus tonsillaris* or the *tonsillar recess* bounded by the palatopharyngeal and palatoglossal arches. The palatopharyngeal arch caused by the underlying palatopharyngeus muscle runs downwards and laterally from the soft palate to this part of the pharynx and between this and the palatoglossal arch is a triangular fossa, the *tonsillar recess* which contains the palatine tonsil.

(3) **Laryngeal part of the pharynx.** The laryngeal part of the pharynx is continuous obove with the oral part of the pharynx ot the level of the hyoid bone and below with the oesophagus at the level of the lower border of the cricoid cartilage opposite the sixth cervical vertebra. It also consists of dorsal or posterior, veotral or onterior and lateral walls. The **dorsal wall** lies opposite the fifth and the sixth cervical vertebrae ond is continuous with the dorsal wall of the oral part of the pharynx above and with the dorsal wall of the oesophagus below. It's **ventral or anterior wall** is formed by the larynx and from obove downward the different compooents are epiglottis, the inlet of the larynx and the anytenoid cartilage and the lamina of the cricoid cartilage. It's **lateral wall** is formed on each side by the pharyngo-epiglottic fold and by the *piriform fossa* which is bounded medially by the larynx and laterally by the inner surface of the lamina of the thyroid cartilage and the hyothyroid membrane.

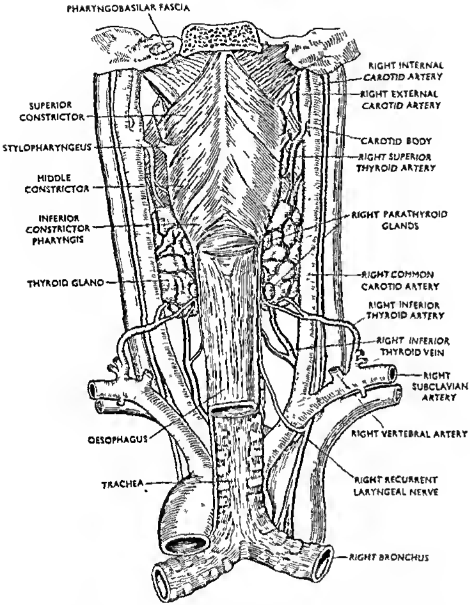
Communications. The nasopharynx communicates with the nasal cavity by the two choanae, with the tympanic cavity by the auditory (pharyngo-tympanic) tube, the opening of which lies on the lateral wall immediately posterior to each choana. The opening of the auditory (pharyngo-tympanic) tube is bounded posteriorly by a thick layer of mucous fold spreading over the pharyngeal end of the cartilaginous portion of the tube and is known as the *processus tuberius* or *tubal elevations.* It also communicates with the oro-pharynx by the naso-pharyngeal or pharyngeal isthmus.

The oral part of the pharynx communicates in front with the oral cavity through the oro-pharyngeal isthmus and below with the laryngo-pharynx.

The laryngo-pharynx is directly continuous with the oesophagus below and it also communicates with the larynx through the laryngeal inlet which is situated at a higher level.

Structurally the pharynx consists of four strata and from without-inwards they are the buccopharyngeal fascia, the muscular wall, the pharyngobasilar fassia and the mucous membrane.

Buccopharyngeal fascia. It is a thin sheet of fascia which covers both the muscles of the pharynx externally and the buccinator muscle. Anteriorly it passes over the pterygomandibular ligament and then is continuous with the fascia covering the outer aspect of the buccinator muscle. Posteriorly opposite the median plane it is fused with the prevertebral fascia. The space between the prevertebral fascia and



The dorsal view of the pharynx with the great vessels and with a part of the oesophagus and trachea.

[To face page 824]

the buccopharyngeal fascia on each side of the median plane, is called the *retropharyngeal space* which contains the retropharyngeal lymph nodes.

Muscular wall of the pharynx. The muscular wall of the pharynx consists of pharyngeal muscles enumerated as below:

(1) Constrictor pharyngis inferior.
(2) Constrictor pharyngis medius.
(3) Constrictor pharyngis superior.
(4) Stylopharyngeus—has been described with the "muscles attached to the styloid process".
(5) Salpingopharyngeus.
(6) Palatopharyngeus—has been described along with the soft palate.

Constrictor pharyngis inferior. It is the thickest and the lowest of the constrictor muscles that come in the construction of the pharyngeal wall and is divisible into two parts, *thyropharyngeus* and *cricopharyngeus*.

The *thyropharyngeus* of the constrictor pharyngis inferior arises by muscular fibres from the oblique line and the adjoining surface of the lamina of the thyroid cartilage and from the inferior thyroid tubercle, and by tendinous fibres from the lateral aspect of the cricothyroid muscle between the above two muscular origins. The muscle fibres are *oblique in direction* and run upwards and backwards and are inserted into the posterior median fibrous raphe where they meet the fellow of their opposite side. *Functionally it is the "propulsive part" of the muscle.*

The *cricopharyngeus part* of the inferior constrictor muscle of the pharynx arises from the lateral side of the cricoid cartilage in the interval between the origin of the cricothyroid in front and the inferior horn of the thyroid cartilage behind. The fibres are *horizontal in direction* and they do not meet in the posterior median raphe and instead they are continuous with the fibres of the opposite side and form the musculature at the opening into the oesophagus. Functionally the cricopharyngeus of the inferior constrictor muscle of the pharynx forms the *sphincteric part* of the inferior constrictor muscle of the pharynx.

Pharyngeal diverticulum. It is a pouch-like evagination of the mucous membrane through the walls of the lower part of the pharynx close to its junction with the oesophagus. It is also known as oesophageal diverticulum, hypopharyngeal diverticulum or pharyngo-oesophageal diverticulum. It is of the nature of a *pulsion diverticulum* (yields due to pressure) that makes its way out through a congenitally weak muscular wall. However, causes other than congenital weakness have also been suggested.

Site. Although opinion varies the usual site of the diverticulum is the *Laimer's triangular area*. It is bounded on either side by the diverging longitudinal fibres at the upper end of the oesophagus, and above by the lower border of the cricopharyngeus muscle. In this part the muscular wall of the oesophagus is formed only by the circular fibres because the posterior longitudinal fibres here instead of forming a continuous covering diverge from the median plane so as to enclose a triangular area known as the Laimer's triangle.

The pharyngeal diverticulum is associated with dysphagia (difficulty in deglutition) with regurgitation of food and occasionally with gurgling sounds.

Operative removal is the usual treatment.

Salpingopharyngeus. It is a small muscle that takes it's origin from the inferior aspect of the cartilaginous part of the auditory (pharyngo-tympanic) tube and is inserted into the wall of the pharynx.

Constrictor pharyngis medius. It arises from the lesser horn and the whole length of the greater horn of the hyoid bone and from the stylohyoid ligament. Its lower fibres descend downwards deep to the inferior constrictor pharyngis, it middle fibres pass transversely and its upper fibres ascend and overlap the superior constrictor muscle. It is inserted into the posterior median fibrous raphe.

Constrictor pharyngis superior. It arises from the pterygoid hamulus and the posterior margin of the medial pterygoid lamina, from the pterygomandibular ligament, from the posterior part of the mylohyoid line of the mandible and from the side of the tongue.

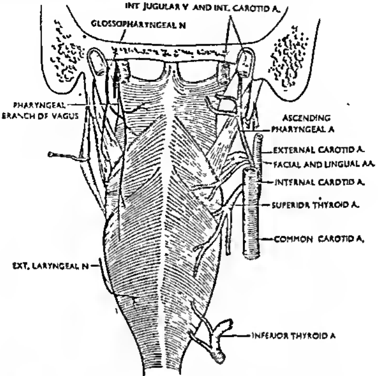


Fig. 693. The constrictor muscles of the pharynx as seen from behind.

Its fibres pass backwards medially and upward and are inserted into the posterior median fibrous raphe and also to the pharyngeal tubercle on the basilar part of the occipital bone by means of pharyngeal aponeurosis.

Structures passing between the constrictor muscles:

(1) *Between the base of the skull and the superior constrictor:*
 (a) Levator veli palatini (levator palati) muscle.
 (b) Auditory (Pharyngo-tympanic) tube.
 (c) Branches of the asceading palatine artery.

(2) *Between superior and middle constrictor:*
 (a) Stylopharyngeus muscle.
 (b) Glossopharyngeal nerve.

(3) *Between middle and inferior constrictors:*
 (a) Internal laryngeal nerve.
 (b) Superior laryngeal artery.

(4) *Between the inferior constrictor muscle and the oesophagus:*
 (a) Recurrent laryngeal nerve.
 (b) Interior laryngeal artery.

Nerve supply. The mucous membrane and the muscles of the pharynx are supplied mostly by the pharyngeal plexus formed by the glossopharyngeal, internal laryngeal and the pharyngeal branches of the vagus and the sympathetics.

Vascular supply. The arteries are the ascending pharyngeal branch of the external carotid, ascending palatine and tonsillar branches of the facial and the greater palatine and pharyngeal branches of the maxillary artery.

The veins drain into the *pharyngeal plexus* which communicates above with the pterygoid venous plexus and opens below into the internal jugular vein.

Motor nerves. All the muscles of the pharynx are supplied by the cranial accessory nerve through the vagus nerve except the stylopharyngeus which is supplied by the glossopharyngeal nerve. The lower portion of the inferior constrictor muscle is supplied by the external laryngeal branch of superior laryngeal nerve (vagus). The transverse fibres of the cricopharyngeus is supplied by the recurrent laryngeal branch of the vagus.

Sensory nerves. The glossopharyngeal nerve (through pharyngeal and tonsillar branches) supplies sensory fibres to the mucous membrane of the whole of the pharynx except the superior portion of the naso-pharynx which is supplied by the pharyngeal branch of the sphenopalatine ganglion, the fibres being derived from the trigeminal nerve.

Lymphatics. The lymphaties draining the upper part of the pharynx end into the deep facial lymph nodes situated along its lateral wall. The lymphatics draining the lower part end into the upper deep cervical lymph nodes. Some lymph vessels from the upper part of the pharynx pass to the retropharyngeal lymph nodes.

Pharyngo-basilar fascia or the pharyngeal aponeurosis. It is a thin layer of fascia that intervenes between the mucous membrane and the muscular wall of the pharynx. Inferiorly it is very thin and delicate but superiorly it is thick and dense and is attached to the basilar part of the occipital bone, apex of the petrous part of the temporal bone, adjoining part of the auditory (pharyngo-tympanic) tube and to the posterior border of the medial pterygoid lamina of the pterygoid process of the sphenoid. The portion attached to the pharyngeal tubercle of the basilar part of the occipital bone is specially thickened to form the fibrous raphe of the pharynx.

Palatine tonsils. The palatine tonsils are the two aggregated masses of lymphoid tissue situated one on each side of the oral part of the pharynx.

Each tonsil is placed on the lateral wall of the oral part of the pharynx in a pocket-like recess, the *tonsillar fossa* (sinus tonsillaris) which is bounded in front by the palatoglossal arch and behind by the palatopharyngeal arch. Its position corresponds on the surface of the body to a point half an inch above and anterior to the angle of the mandible.

Each tonsil is covered by a layer of fibrous tissue on its deep or lateral surface and is known as the *capsule of the tonsil.* Its medial surface is devoid of any capsule.

The organ is shaped like that of an almond and has two surfaces—lateral and medial; two borders—anterior and posterior; two poles—superior and inferior.

Medial surface. This surface looks inwards towards the cavity of the mouth and on it there are 12-20 openings which are leading into small recesses known as the *tonsillar pits.*

Lateral surface. The lateral surface of the tonsil is covered by a fibrous capsule (the capsule of the tonsil) which separates it from its muscular bed formed by the superior constrictor pharyngis, palatopharyngeus, stylopharyngeus and the styloglossus. The capsule of the tonsil is connected to its muscular bed by a layer of loose cellular tissue except postero-inferiorly where the palatopharyngeus muscle gains insertion into it.

The *lateral surface* of the tonsil has some important *vascular relations.* The facial artery and its tonsillar and ascending palatine branches are separated from it by its muscular bed. A long vein (the paratonsillar vein) descends from the soft palate and intervenes between the capsule and the muscular bed of the sinus tonsillaris and it soon pierces the muscular wall to end into the pharyngeal venous plexus. The internal carotid artery lies about one inch postero-lateral to the tonsil and is separated from the pharyngeal wall by loose areolar tissue and fat.

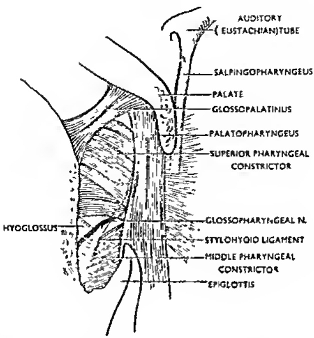


Fig. 694. The muscular bed of the palatine tonsil. With kind permission from Prof. W. H. Hollinshead, Ph.D.; Anatomy for the Surgeons, Vol. I, Paul B. Hoeber INC.

The glossopharyngeal nerve forms the important *nervous relation* to the lateral surface of the tonsil being separated from it by the muscular wall of the sinus tonsillaris.

The *other structures* coming into relation with the lateral aspect of the tonsil are the stylohyoid ligament and sometimes the styloid process when it is too long.

The *upper pole* of the tonsil presents a deep intratonsillar cleft, frequently termed the supratonsillar fossa. The *lower pole* lies in contact with the side of the tongue.

The *anterior border* is in relation with the palatoglossal arch containing the palatoglossus muscle while the *posterior border* is in relation with the palatopharyngeal arch containing the palatopharyngeus muscle.

Artery supply. Although the tonsillar branch of the facial artery is the main artery supply of the tonsil, five arteries supply the tonsil which enter into it through its lower and upper poles, three at the lower pole and two at its upper pole.

(1) Tonsilar branch of dorsal linguae artery enters the tonsil anteriorly at the lower pole.
(2) Tonsillar branch of the ascending palatine enters the tonsil posteriorly at the lower pole.
(3) Tonsillar branch of facial artery enters the tonsil in between the two above arteries at the lower pole.
(4) Tonsillar branch of lesser palatine artery.
(5) Tonsillar branch of ascending pharyngeal artery. Both entering the tonsil at the upper pole.

Venous drainage. The veins draining the tonsil form plexus around its capsule and open into the pharyngeal plexus. The paratonsillar vein also opens into the pharyngeal plexus by piercing the muscular wall of the tonsil.

Lymphatics. Most of the lymphatics draining the tonsil end into the jugolo-digastric group of the upper deep cervical lymph nodes. Some lymph vessels, however, open into submaxillary and superficial cervical lymph nodes.

Development. The persistent ventral portion of the second pharyngeal pouch forms the tonsillar recess into which there is proliferation of the entodermal cells

lining the recess. The entodermal proliferation is later on invaded by the mesoderm and the combined entodermal and mesodermal cell-mass forms the primordium of the tonsil. During the fifth month of intrauterine life the connective tissue of the primordial tonsil shows lymphatic aggregations which develop either in situ or they are derived from the blood stream and thus the fully formed tonsil is developed.

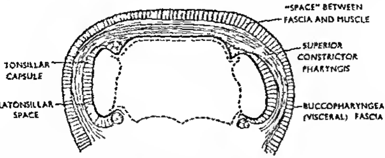


Fig. 695. The transverse section of the oral part of the pharynx. Note the position of the tonsils. With kind permission from Prof. W. H. Hollinshead: Anatomy for the Surgeons, Vol. I, Paul B. Hoeber INC.

Auditory (Pharyngo-tympanic) tube. It is an oesofibrocartilaginous tube connecting the tympanic cavity with the nasal part of the pharynx. It is about one and a half an inch in length and is directed downwards, forwards and medially. It consists of a bony part which measures about half an inch and a cartilaginous part measuring about one inch.

The **bony part** begins from the anterior wall of the tympanic cavity and ends in the cartilaginous part at the junction of the petrous and squamous parts of the temporal bone.

The **cartilaginous part** consists of a triangular plate of cartilage which is bent on itself in its longitudinal axis and is bent into a lateral and a medial lamina; the two laminae do not meet to each other and thus a gap exists on the lateral side which is bridged over by a layer of fascial lamina connecting the two free margins of the cartilaginous laminae. The apex of the triangular cartilage is attached to the jagged margin of the bony part of the tube. The base of the cartilage forms an elevation at the nasal part of the pharynx and the mucous membrane covering it is known as the *tubal elevation.* The cartilaginous portion rests in a shallow groove—the *sulcus tubae* on the base of the skull which is formed by the articulation between the petrous part of the temporal bone and the posterior border of the greater wing of the sphenoid bone. Its opening into the lateral wall of the nasopharynx is bounded by the tubal elevation. The tube is constricted at the junction of the cartilaginous and bony parts and is known as the *isthmus.*

Relations. *Antero-laterally* the cartilaginous portion of the tube is in relation with the tensor palati muscle which separates it from the otic ganglion, the mandibular nerve and its branches, the chorda tympani nerve and the middle meningeal artery. *Postero-medially* the tube is related to the petrous part of the temporal bone and to the levator palati muscle. In other words, the tube is sandwitched between the tensor palati muscle on the lateral side and the levator palati muscle on the medial side. The portion of the tensor palati muscle arising from the cartilaginous part of the tube constitutes the *dilator tubae.*

Nerve supply. It is supplied by the tympanic branch of the glossopharyngeal and the pharyngeal branch from the sphenopalatine ganglion.

Vascular supply. The arteries supplying the tube are derived from the ascending pharyngeal, middle meningeal and the pterygoid arteries. Its veins open into the pterygoid venous plexus.

N.B. Through the pharyngo-tympanic tube air is communicated to the tympanic cavity from the nasal part of the pharynx. Tympanic cavity having thus communicated to the nasal part of the pharynx,

adds to the auditory acuity in allowing the tympanic membrane to vibrate properly; under certain pathological conditions the pharyngo-tympanic tube is blocked and under such conditions auditory acuity is lost.

Development. The dorsal portion of the first pharyngeal pouch instead of obliterating becomes pouch-like and together with the adjacent pharyngeal wall and the second pharyngeal pouch it forms a recess the *tubo-tympanic recess* which intervenes between the dorsal ends of the first and the third arch cartilages. The tubo-tympanic recess elongates as a diverticulum and invades the ectoderm of the first pouch and from its proximal narrower portion, later on, the auditory (pharyngo-tympanic) tube develops and from its distal dilated end the middle ear develops. Another diverticulum from the middle ear forms the epitympanic resess and the mastoid antrum and from the latter, the mastoid air cells.

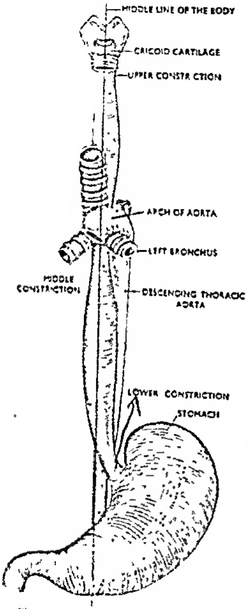


Fig. 776. The natural constrictions and the curvatures of the oesophagus.

THE OESOPHAGUS

The oesophagus or the gullet is a muscular tube meant for transporting food from the mouth and pharynx to the stomach.

Measurement. It measures about 9-10 inches in length.

Commencement, general course and termination. It begins at the level of the lower border of the cricoid cartilage, opposite the sixth cervical vertebra, as a direct continuation of the pharynx and descending vertically downwards through the neck, the superior and posterior mediastinums of the thorax, it pierces the diaphragm opposite the level of the tenth thoracic vertabra and enters the abdomen, where it ends at the cardiac end of the stomach opposite the level of the eleventh thoracic vertebra.

Curvatures. Though the general direction of the oesophagus is vertical, yet when carefully observed it presents two lateral and two antero-posterior curvatures. At its beginning in the neck it is placed at the middle line of the body and then gradually passes to the left side and opposite the level of the fifth thoracic vertebra it again approaches to the middle line from where it descends downwards having an inclination again to the left and immediately above the oesophageal opening in the diaphragm it again approaches to the middle line and passes in front of the descending thoracic aorta before it disappears into its opening in the diaphragm. The antero-posterior curvatures of the oesophagus correspond to the cervical and thoracic curvatures of the vertebral column.

On the left side (in the superior mediastinum):
(1) Terminal part of the arch of the aorta.
(2) Left subclavian artery.
(3) Left pleura.
(4) Left recurrent laryngeal nerve which ascends upwards in the groove between the trachea and oesophagus.
(5) Thoracic duct.
(In the posterior mediastinum)
(6) Descending thoracic aorta.
(7) Left pleura.

On the right side:
(1) Right pleura.
(2) Azygos vein.

Abdominal part. It is the smallest sub-division of the oesophagus and measures bout half an inch in length. It is lodged in the oesophageal groove of the liver. t is covered by peritoneum both in front and at the sides.

N.B. The thoracic duct bears an important relation with the oesophagus. In the posterior ıediastinum it lies behind and to the right of the oesophagus, then higher up it lies behind, and opposite ıe level of the fourth thoracic vertebra, it crosses posterior to the oesophagus and then reaches its ft side. The oesophagus presents three constrictions—one at its beginning, one behind the left bronıus and third opposite the oesophageal opening of the diaphragm. (For convenience the oesophagus ıs been described as a whole and the students dealing with the head and neck are concerned only with ı cervical part).

Artery supply. Arteries supplying the oesophagus are four in number and they ıre as follows.
(1) Oesophageal branch of the inferior thyroid—upper part.
(2) Oesophageal branches of the descending thoracic aorta and the bronchial arteries.
(3) Oesophageal branch of the left gastric.
(4) Oesophageal branch of the left inferior phrenic artery—abdominal part.

Venous drainage. The veins draining the oesophagus arrange in a plexiform ıetwork in the submucosa from which branches pass through the musculature to oin another venous plexus on its external aspect. The upper part of the external 'enous plexus is drained by the *inferior thyroid vein*, its middle portion by the *azygos* ınd *hemiazygos veins* while its lower part is drained by the *gastric veins*.

Lymphatics. The lymphatics draining the upper part of the oesophagus terminate nto the *para-tracheal* and the *inferior deep cervical lymph nodes*, its middle part into the *ronchial lymph nodes* while those from its lower part terminate into *posterior mediastinal ymph nodes*, the efferents from which pass to the coeliac and suprapancreatic lymph ıodes.

Nerve supply. The oesophagus is supplied by both sympathetic and para-sympathetic fibres. The sympathetic fibres are derived from the cervical and the horacic sympathetic chains while the para-sympathetic fibres are derived from the ·agus nerve.

In the neck. The cervical portion of the oesophagus is supplied by the ympathetic fibres which are derived from the plexus of sympathetic nerves around the inferior thyroid arteries, fibres being derived from the cervical sympathetic trunks. The para-sympathetic fibres are supplied by both recurrent laryngeal branches of the vagus.

In the thorax. The thoracic portion of the oesophagus is supplied by the oesophageal plexus, the sympathetic fibres being derived from the upper thoracic ganglia and from the greater and the lesser splanchnic nerves, and the para-sympathetic fibres from both vagus nerves.

IN THE ABDOMEN. The sympathetic supply for the abdominal portion of the oesophagus is derived from 6th to 10th thoracic ganglia, from the greater and the lesser splenchnic nerves and from the plexus of sympathetic nerves around the left gastric and the phrenic arteries. The para-sympathetic fibres are derived from the oesophageal plexus (vagus).

Development. The premitive oesophagus arises from the caudal portion of the foregut and at first forms a short tube which extends from the tracheal groove to the fusiform dilatation (which is the future stomach) of the foregut. It descends on the posterior aspect of the septum transversum, and in the upper part, it lies in front of the notochord and behind the tracheal groove. Then with the rapid growth of the lung bud and with the caudal descent of the heart, the oesophagus rapidly lengthens and in consequence, its canal is temporarily obliterated but with normal development soon it is recanalized and becomes continuous with the stomach. The visceral mesoderm that surrounds it gives rise to its musculature and connective tissue elements. The musculature at its upper two-thirds is voluntary in function and straited while in its lower one-third it is involuntary and non-straited.

N.B. Failure of re-establishment of canalization of the oesophagus results in congenital atresia of the same.

Mechanism of deglutition. The mechanism of deglutition or the act of swallowing is a complicated process in which the muscles of the mouth, tongue, palate, pharynx, the supra - and infrahyoid muscles and the muscles of the oesophagus are involved. By this co-ordinated, successive activities of the above group of muscles, the bolus of food is received into the mouth cavity, then it is thrown back into the pharynx and finally the food passes through the oesophagus into the stomach. Thus, for convenience, the mechanism of deglutition can be divided into three stages as follows, although it is a one continuous process.

First stage or the stage of voluntary activity. In this stage the food is received into the mouth cavity and then is thrown back into the pharynx. If the food is solid it is bitten repeated by the teeth by the movement of the jaws and then the bolus is transferred to the pharynx. The following mechanism comes into play during this stage.

First the mouth is opened by the depression of the lower jaw, the tongue protrudes to lie over the lower lip by the transversus linguae, the food is received and then it is carried to the mouth cavity by the retraction of the tongue by the contraction of the styloglossus and the anterior part of the genioglossus muscles; if required, it is chewed by the muscles of mastication and then it becomes ready for swallowing. The mouth is closed by the masseter and temporalis and the lips are approximated by the orbicularis oris; the tip of the tongue then presses on the anterior part of the hard palate by the genioglossus and the food lies on a gutter formed over the dorsum of the tongue by the longitudinalis linguae superioris; at this stage a tubular path is formed between the gutter on the dorsum of the tongue and the concavity of the hard palate which is continuous with the oropharyngeal isthmus and the pharynx. Then this tubular path is gradually obliterated from before backwards by the pressure of the dorsum of the tongue against the hard palate caused by the contraction of the longitudinalis linguae inferior and by relaxation of the genioglossi muscles. With this the bolus of food rolls back through the oropharyngeal isthmus towards the oropharynx; at this stage the soft palate is elevated by the levator palati muscles and the nasopharynx is closed from the oropharynx by the soft palate; then the bolus of food is thrown further backwards by the depression of the root of the tongue and by the elevation of the hyoid bone and the larynx by the mylohyoid muscles, finally the stylopharyngeus muscle elevates the pharyngeal wall cranially over the bolus of food and the root of the *tongue acts as a piston* (like a piston of a syringe) in thrusting the bolus of food caudalwards into the pharynx by bulging dorsally and caudally against the posterior wall of the oropharynx. During the elevation of the larynx the epiglottis closes the vestibule of the larynx.

Second stage or the stage of involuntary activity. In this stage the bolus of food passes through the pharynx. Once the food reaches the pharynx the process becomes an

ıvoluntary one and the bolus of food is carried downwards by the successive con-:action of the constrictor muscles of the pharynx to the oesophagus.

Third stage. This is also an involuntary stage in which the musculature of the esophagus progressively contract caudalwards to empty its content into the stomach. At the end of the first stage, the tongue, larynx, hyoid bone and the epiglottis ttain their normal position

ABDOMEN

Abdominal walls. The walls of the abdominal cavity are so adapted that high egree of expansion of the abdominal cavity is permitted without any obstruction and ·ith least resistance because the greater part of the walls of the abdomen is fibro-ıuscular. Its walls are anterior and posterior. In an articulated skeleton the gap ·elow the costal arch and the lower end of the sternum is closed up by a bro-musculo-serous wall which constitutes the anterior abdominal wall. Poste-iorly the vertebral column occupies the median plane and on either side of it, from bove downwards, are the lower ribs, a gap between the lowest ribs and the iliac rest and the iliac fossa of the hip bone. The gap between the iliac crest and the ɔwer border of the last rib is filled up by the quadratus lumborum which is enshea-hed by two layers of fasciae (anterior and the middle layers of the lumbar fascia) vhich meet at its lateral border and then joins with the posterior layer of the lumbar ascia. From the lateral border of the fused lumbar fascia the transversus abodminis nuscle arises and spreads transversely across the anterior abdominal wall. Thus ve see that the posterior abdominal wall is an osseo-musculo-fibrous wall and its :omparative weaker part corresponds to the gap between the lowest rib and the liac crest.

Anterior abdominal wall. If we look to the anterior abdominal wall we find ı linear vertical groove opposite the median plane which corresponds to the *linea ılba*, a longitudinal fibrous band extending from the xiphoid process to the sym-ɔhysis pubis. On either side of the groove for the linea alba the longitudinal nuscular prominence is caused by the rectus abdominis, lateral to which is a linear :urved groove, the *linea semilunaris* which corresponds to the division of the aponeurosis ɔf the internal oblique muscle at the lateral border of the rectus abdominis. The nost conspicuous feature of the anterior abdominal wall is the presence of the ımbilicus which lies opposite the level of the fibro-cartilage between the third and he fourth lumbar vertebrae.

Structural arrangement of the anterior abdominal wall. The construction of the ınterior abdominal wall is such that the two recti muscles, one on each side of the nedian plane, form flattened muscular pillars anteriorly and connecting them with posterior pillars, formed by the vertebral column, the sacrospinalis and the quadratus lumborum muscles, are the three flat muscles, namely, obliquus externus ıbdominis, obliquus internus abdominis and the transversus abdominis. If we nake a transverse section through the anterior abdominal wall the following anatomical facts in the construction of its wall will be noticed.

Opposite to the median plane—(Structures from without inwards). The structures are the skin, superficial fascia, linea alba, transversalis fascia, extraperitoneal connective tissue and the peritoneum.

Opposite to the prominence caused by the rectus abdominis—(from without inwards). The structures are the skin, superficial fascia, anterior wall of the rectus sheath, rectus abdominis muscle, vessels and nerves, posterior wall of the rectus sheath, transversalis fascia, extraperitoneal connective tissue and the peritoneum.

Opposite to the linea semilunaris—(from without inwards). The structures are the skin, superficial facia, aponeurosis of the three flat muscles of the abdomen, transversalis fascia, extraperitoneal connective tissue and the peritoneum.

From the above anatomical facts it is evident that the portion of the anterior abdominal wall corresponding to the linea alba is entirely fibrous and consequently

less vascular. Hence, safest approach to the abdominal cavity may be undertaken through this line. The line opposite the linea semilunaris is also fibrous and less vascular but the nerves supplying the rectus abdominis, which are segmental in distribution, traverse this space and an approach to the abdominal cavity through this line has a possibility for the nerves to be injured.

Compensation of the week anterior abdominal wall. Of necessity nature has provided a softer and a weaker anterior abdominal wall but this weakness is much compensated for by the arrangement of its muscular wall which affords sufficient protection for the internal organs. The two straight muscles on either side of the median plane are sufficiently strong to protect the internal organs anteriorly. Remember an athlete of good physique can resist the weight of a motor car being run over across the abdomen with the contraction of his recti. Antero-laterally the three flat muscles are arranged in such a way that they are placed one above the other and the muscle fibres of one cross those of the other and vice versa. This arrangement strengthens the anterior abdominal wall and affords sufficient protection for the internal organs.

Regions on the anterior abdominal wall. In order to ascertain the respective position of internal organs in the abdominal cavity, the anterior abdominal wall has been divided into different regions by drawing different straight lines at different levels or planes. There are altogether nine regions in the anterior abdominal wall and they are demarcated as follows : Draw a transverse line across the anterior abdominal wall connecting the tips of the tenth rib and this line is known as the TRANSPYLORIC LINE. A second transverse line is drawn opposite the highest point of the iliac crest and this is known as TRANSTUBERCULAR LINE. Thus we see that these two lines divide the anterior abdominal wall into three zones or areas—upper, middle and lower. Two vertical lines, one on each side, are drawn perpendicularly upwards from the middle of the inguinal ligaments and they will cross the transtubercular and transpyloric lines at right angles. Now it is obvious that each of the upper, middle and lower areas demarcated by the transtubercular and transpyloric lines, is further divided into three areas by these vertical lines. The upper area is divided into right and left hypochondriac regions on the lateral sides of the two corresponding vertical lines and into epigastric region which lies in between the vertical lines. Similarly, the middle area is dividing into right and left lumbar regions and the umbilical region while the lower area is divided into right and left inguinal regions and the hypogastric region.

N.B. Sometimes a transverse line is drawn across the anterior abdominal wall opposite the most dependent part of the tenth rib and this line constitutes the sub-costal plane or line.

Contents of Individual Region:

(1) Epigastric region:

(a) Stomach.
(b) First part of duodenum.
(c) Left lobe of the liver.
(d) Medial end of the spleen.
(e) Pancreas.
(f) Left suprarenal gland.

(2) Right hypochondriac region:

(a) Right lobe of the liver.
(b) Gall bladder.
(c) Right colic flexure.
(d) Right half of the transverse colon.

(3) Left hypochondriac region:

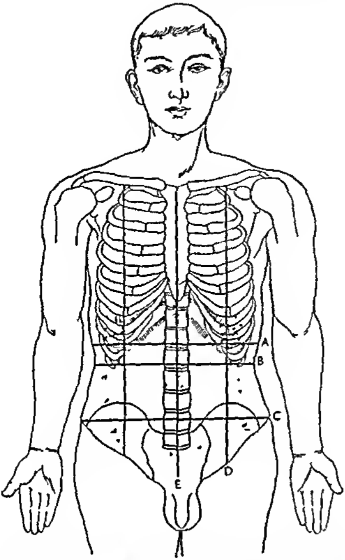
(a) Stomach.
(b) Spleen.
(c) Left colic flexure.
(d) Left half of the transverse colon.
(e) Tail of the pancreas.

(4) Umbilical region:

(a) Small Intestine.
(b) Pancreas.
(c) Duodenum.

(5) **Right lumbar region:**
- (a) Right kidney.
- (b) Ascending colon.

(6) **Left lumbar region:**
- (a) Left kidney.
- (b) Descending colon.



A=Transpyloric plane B=Subcostal plane C=Transtubercular plane
D=Left lateral plane E=Median plane

Fig. 700. The planes of the anterior abdominal wall.

(7) **Right inguinal region:**
- (a) Caecum.
- (b) Vermiform appendix.
- (c) Terminal portion of the ileum.
- (d) Commencement of the ascending colon.

(8) **Left inguinal region:**
Pelvic colon.

(9) **Hypogastric region:**
- (a) Urinary bladder.
- (b) Rectum.
- (c) Prostate and seminal vesicles in case of male.
- (d) Uterus, ovary and uterine tube in case of female.

Superficial fascia of the anterior abdominal wall. The superficial fascia of the abdomen forms the general investing fascia and is continuous above with the superficial fascia of the thorax. Below, opposite the inguinal region it divides into two distinct layers, a superficial adipose or fatty layer and a deep membranous layer.

Superficial adipose layer or the fascia of Camper. The superficial adipose layer of the superficial fascia of the abdomen forms an areolar membrane which contains fat in its meshes, and superiorly, above the line joining the two anterior superior iliac spines, it is fused with the deep layer. Traced medially, it is continuous with the fellow of its opposite side. Traced downwards, opposite the symphysis pubis, it passes in front of the spermatic cord and then covers the penis and scrotum. In the scrotum its adipose tissue is replaced by muscular fibres and forms the dartos muscle in this situation. In the female it passes along the round ligament of the uterus to the labia majora. Opposite the inguinal ligament it passes over the inguinal ligament and is fused with the deep fascia along the *Holden's line*, a straight line that passes transversely from the pubic tubercle to the lateral side.

Deep membranous layer or the fascia of Scarpa. The deep membranous layer of the superficial fascia of the abdomen contains many elastic fibres and superiorly it is fused with the adipose layer above the level of the anterior superior iliac spines. Medially it is adherent to the linea alba by fibrous bands opposite the median plane. Opposite each half of the symphysis pubis it passes along the spermatic cord and is continued to the penis and the scrotum and is then continuous with the fascia of Colles or the deep layer of the superficial fascia of the perineum. Opposite the middle line it forms a distinct band which soon separates into two bundles to embrace the root of the penis and are fused with the sheath of the penis. These bands are called the *suspensory ligament of the penis*. Opposite the inguinal ligament its medial portion is fused with the inguinal ligament but its lateral portion passes over the inguinal ligament for a distance of about one inch and ends below by fusing with the deep fascia of the thigh along the Holden's line. The superficial epigastric artery ascends upwards passing superficial to inguinal ligament and intervenes between the adipose and the membranous layers. The superficial inguinal lymph nodes also lie between these two layers of fascia below the inguinal ligament.

N.B. The deep layer of the superficial fascia being continuous with the deep layer of the superficial fascia of the perineum extravasated urine under the latter ascends upwards into abdominal wall and accumulates under the fascia of Scarpa or the deep layer of the superficial fascia of the abdomen. It cannot go into the front of the thigh because the fascia of the Scarpa is adherent to the fascia lata and consequently the accumulated urine passes upwards in the areolar space between the fascia of Scarpa and the obliquus externus abdominis.

When the flat and the recti muscles have been removed the anterior abdominal wall will be seen to be formed by a thin glistening, transparent cloth-like structure known as the peritoneum. Lying superficial to the peritoneum is a thin layer of areolar tissue on which there lies a delicate fascia known as the *transversalis fascia*. On a general view the peritoneum, extraperitoneal connective tissue and the transversalis fascia will be found as a single layer of membranous structure, but when a light incision is given the transversalis fascia retracts from the cut margin and it is seen to be a distinct layer of fascia which is spread on the loose extraperitoneal connective tissue.

Transversalis fascia. It is the general investing fascia on the anterior abdominal wall situated beneath the transversus abdominis muscle and in the front of the extraperitoneal connective tissue. Above, it is continuous with the fascia covering the under-surface of the diaphragm. Below, opposite the iliac crest, it is attached to the whole length of the inner lip of the iliac crest between the iliacus and the transversus abdominis. Opposite to the lateral half of the inguinal ligament it is attached to the under-surface of the same ligament and is fused with the fascia iliaca. Opposite to the femoral vessels it is attached to the under-surface of the inguinal ligament and then is continued downward in front of the femoral vessels. Medial

the femoral vessels it is fused with the deep aspect of the conjoined tendon and is ially attached to the pectineal line. Posteriorly it is fused with the lumbar fascia nterior layer).

ABDOMINAL CAVITY

The disposition of the transversalis fascia and the extra-peritoneal connective ssue having been seen the abdominal cavity may be opened by a cruciate incision pposite the level of the umbilicus. Reflect the upper two flaps upwards over the ostal arch and the lower two flaps downwards and verify its different boundaries. he whole abdominal cavity is divided into *abdomen proper* and the *pelvic cavity* by the elvic brim; the portion lying below the pelvic brim is the pelvic cavity and the ortion lying above it is the abdomen proper.

Boundaries of the abdo-inal cavity:

Superiorly. It is bounded by e concave under-surface of the aphgram which separates the odominal and thoracic cavities om each other.

Inferiorly. It is bounded by e upper concave surface of the lvic and the urogenital dia-iragms.

Anteriorly. Anteriorly and oove, a considerable portion of e abdominal cavity is bounded the back of the costal arch. nteriorly and below the pelvic ortion of the abdominal cavity bounded by the back of the mphysis pubis. In between iese two points the anterior all is formed by the back of the nterior abdominal wall which a fibro-musculo-serous wall.

Laterally. Laterally and bove, it is formed by the costal rch, and laterally and below, it formed by the hip bone. In etween the iliac crest and the st rib it is formed by the flat uscles of the anterior abdomi-al wall.

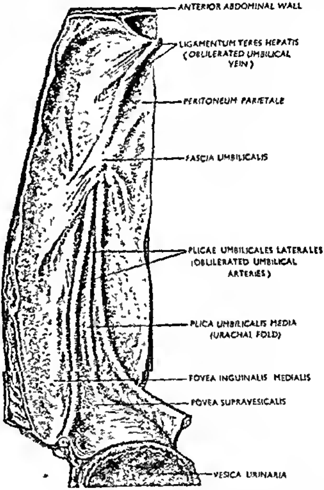


Fig. 701. The umbilical region—seen from behind. With kind permission from Callanders Surgical Anatomy, W. B. Saunder's Company; Philadelphia and London.

Posteriorly. Opposite to the pigastric, and the right and ft hypochondriac regions it is rmed by the vertebral column in the median plane and on each side of the median lane by the quadratus lumborum together with the lumber fascia. Opposite to e inguinal fossa it is formed by the iliac fossa of the hip bone and by the lumbar ertebrae in the umbilical region. Opposite to the pelvic cavity the posterior wall formed by the anterior surface of the sacrum and the coccyx.

Dispositions of the abdominal viscera. The diaphragm muscle forms the roof of he abdominal cavity under the concavity of which, opposite the right hypochondriac nd the epigastric region, there lies the muddy coloured, solid organ, the *liver* which

is divided into right and left lobes by the falciform ligament which connects it with the diaphragm and the anterior abdominal wall. Lying on the under-surface of the liver and just peeping out of its sharp inferior margin, opposite to the tip of the ninth costal cartilage is the globular fundus of the *gall bladder*. Lying opposite to the left hypochondriac and the epigastric regions the dilated hollow viscus is the *stomach*. Behind the left side of the stomach the muddy coloured solid organ is the *spleen* which lies against the diaphragm which separates it from the 9th, 10th and 11th ribs. From the lower border (greater curvature) of the stomach there hangs the greater omentum, an apron-like fold of peritoneum popularly called the 'Police man of the abdomen', which hides the intestines from view. The greater omentum being thrown over the costal arch the small intestine surrounded by the large intestine will be exposed. Lying below the greater curvature of the stomach and connected with it by the greater omentum (gastro-colic ligament) is the *transverse colon* which stretches transversely across the abdominal cavity. Passing backwards from the transverse colon is a broad fold of peritoneum known as the *transverse mesocolon* which is attached posteriorly to the anterior border of the pancreas, an elongated gland, that stretches transversely across posterior abdominal wall. Opposite to the right and left ends, the transverse colon joins the ascending and the descending colon respectively at an angle and these angles are called the *right* and the *left colic flexure* respectively. Lying behind the colic flexure, on each side of the vertebral column and opposite to the eleventh thoracic to the third lumbar vertebra is the corresponding *kidney*. Lying immediately behind the symphysis pubis is the *urinary bladder* and lying behind it and in front of the sacrum is the *rectum*. In the female lying in between the urinary bladder and the rectum is the *uterus*. Extending from the uterus to the side wall of the pelvis, the broad fold of peritoneum is known as the *broad ligament* which ends above in a free border which corresponds to the position of the *uterine tube* of the uterus. Attached to the posterior surface of the broad ligament by the mesovarium (fold of peritoneum) is the *ovary*. Below and in front of the uterine tube the cord-like structure is the *round ligament of the uterus* and below and behind the uterine tube the cord-like structure is the *ligament of the ovary*.

Coming back to the stomach it is seen that its right conical extremity forms its pyloric end which terminates in the small intestine. The small intestine consists of three parts, duodenum, jejunum and the ileum. The duodenum begins as the direct continuation of the pyloric end of the stomach and at first ascends upwards, then descends downwards on the side of the vertebral column and then crosses transversely across the vertebral column in front of the abdominal aorta and finally ends in the duodeno-jejunal flexure, opposite to the left side of the second lumbar vertebra. From the duodeno-jejunal flexure the jejunum begins and without having any line of demarcation it becomes continuous with the ileum. Both the jejunum and the ileum are suspended from the posterior abdominal wall by a broad fold of peritoneum known as *the mesentery*. Opposite to the right iliac fossa the ileum ends by entering into a dilated pouch known as the *caecum*. Inferiorly the caecum ends blindly and from its posterior-medial part the worm-like *vermiform appendix* projects downwards. Continuous with the upper end of the caecum is the *ascending colon* which ends in the *right colic flexure* from where the *transverse colon* begins and passing across the abdominal cavity ends in the *left colic flexure*. The *descending colon* begins from the left colic flexure and ends in the pelvic colon opposite to the pelvic brim. The *pelvic colon* begins from the descending colon and ends in the *rectum* opposite to the third sacral vertebra. A broad fold of peritoneum connects it to the pelvic wall known as the *pelvic mesocolon*. The rectum ends in the *anal canal* which ends in the *anus*.

PERITONEUM

It is the largest serous sac in the body and is a closed sac in the males. In the females it communicates with the uterine cavity through the uterine tubes and so to the outside via the cervical canal and the vagina. Like the pleura it consists of a *parietal portion* lining the abdominal parieties and a *visceral portion* covering the viscera to

hich it is attached by areolar tissue. All the viscera are outside the cavity of the ic though they are more or less completely invested by the visceral layer of the eritoneum. The parietal layer is closely adherent to the under-surface of the iaphragm and also to the middle line of the front of the anterior abdominal wall nd elsewhere it is loosely attached. In order to trace the lines of reflections of the eritoneum it is traced both vertically and horizontally, so that, its disposition may e clearly understood.

Traced vertically. Beginning from the umbilicus upwards it covers the oblite-ated umbilical vein or ligamentum teres, which passes from the umbilicus to the nder-surface of the liver. While investing the ligament it forms a triangular fold, e falciform ligament of the liver, which attaches the upper and anterior surfaces of he liver to the diaphragm and to the anterior abdominal wall. From its ttachment to the diaphragm it is reflected on the upper surface of the ight lobe of the liver as the *superior layer of the coronary ligament* and on the upper urface of the left lobe as the *superior layer of the left triangular ligament of the liver*. The uperior layer of the coronary ligament covers the superior and the anterior surfaces

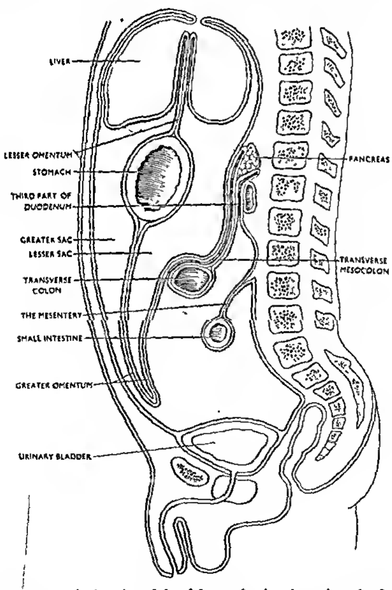


Fig. 702. The sagittal section of the abdomen showing the peritoneal reflections (Diagrammatic)

of the right lobe of the liver and then passing around the inferior margin it is continued on to the under-surface of the liver. In the under-surface of the liver the peritoneum has the following dispositions. (*i*) To the right of the porta hepatis the layer passes to the posteriormost limit of the inferior surface of the right lobe of the liver and then passes as the *inferior layer of the coronary ligament* to the diaphragm and is then reflected to the right suprarenal body and to the right kidney and then runs towards the median plane covering the duodenum, right colic flexure and the inferior vena cava and is continuous with the posterior wall of the *omental bursa* (lesser sac). Note that between the two layers of the coronary ligament a considerable area of the liver is devoid of peritoneum forming the *Bare area of the liver*. The layers of the coronary ligament gradually approach each other at the right margin of the liver and finally are fused together forming a triangular ligament on the right side, the *right triangular ligament*, and the layers similarly meet at the left margin of the liver forming a triangular fold, the *left triangular ligament*.

(*ii*) Opposite the level of the porta hepatis the peritoneum at first covers the quadrate lobe and the under-surface and the sides of the gall bladder and then is attached to the anterior margin of the porta hepatis and then covers the portal vein, hepatic artery and the bile ducts from in front and then turns round the right margin of these structures and covers them from behind and is attached to the posterior margin of the porta hepatis. Thus at the porta hepatis it forms two layers, anterior and posterior, which are continuous with each other round the right margin of the structures of the porta hepatis. Traced to the left the two layers reach the bottom of the fissure for the ligamentum venosum and then diverge as right and left layers. The left layer is continuous with the peritoneum covering the under-surface of the left lobe of the liver whereas the right layer is continuous with the peritoneum covering caudate lobe and the caudate process of the liver. Traced downwards the layer in front of and behind the structures of the porta hepatis forms the corresponding layer of the lesser omentum.

(*iii*) On the left of the porta hepatis it covers the inferior surface of the left lobe and passes backwards up to its posterior margin where it is fused with the superior layer of the left triangular ligament. Traced to the right this layer reaches the bottom of the fissure of the ligamentum venosum where it forms the left layer of the two folds that extend from the porta hepatis. From the level of the porta of the liver the anterior layer passes downwards as the superficial layer of the hepato-gastric and hepato-duodenal ligament (gastrohepatic omentum) and passes to the lesser curvature of the stomach and the first portion of the duodenum. Then the anterior layer passes over the antero-superior surface of the stomach to its greater curvature. Traced downwards, it descends as the anterior layer of a free fold called the greater omentum. Reaching its free margin it is reflected upwards as the posterior layer of the greater omentum and covers the anterior and superior surfaces of the transverse colon, goes backwards in front of the transverse mesocolon to the anterior surface of the head in a line with the superior border of the pancreas. Then it covers the lower part of the anterior surface of the head and the anterior surface of the body of the pancreas to reach its anterior border. Then it runs forwards as the superior layer of the transverse mesocolon, covers the posterior, superior, anterior and inferior aspects of the transverse colon and runs backwards to the anterior border of the pancreas as the inferior layer of the transverse mesocolon. Then it covers the inferior surface of the body of the pancreas and is reflected on to the superior mesenteric vessels forming the anterior layer of the mesentery and covers the small intestines. Then it encircles the small intestines and is attached to the posterior abdominal wall forming the posterior layer of the mesentery. From its posterior attachment it passes downwards covering the aorta into the pelvis. In the pelvis it covers the pelvic colon to form the pelvic mesocolon and then covers at first the sides and front of the rectum and then only the front of its middle third and is reflected into the upper part of the seminal vesicle and the superior surface of the bladder. From here it is reflected on to the anterior abdominal wall covering the medial and lateral umbilical ligaments up to the umbilicus from where we started.

In order to ascertain the HORIZONTAL DISPOSITION of the PERITO-EUM it should be traced at the following levels.

(1) Above the level of the transverse colon.
(2) Below the level of the transverse colon.
  (a) In the lower abdomen.
  (b) In the pelvis.

ı the upper abdomen above the level of the transverse colon:

(a) **Main cavity:** Beginning on the posterior abdominal wall at the inferior ena cava on the right side and traced to the right, the peritoneum passes in front of ıe right suprarenal gland and upper part of right kidney and then to the anterior bdominal wall. In the middle line anteriorly it invaginates the obliterated umbili-al veins forming the falciform ligament of the liver. Traced to the left it covers ıe lateral wall of the abdomen and then reflected on the lateral part of the anterior ırface of the left kidney which it covers. From here it is reflected on the posterior spect of the hilum of the spleen forming the posterior layer of the lieno-renal liga-ıent. It then covers the surfaces of the spleen and is reflected on to the anterior spect of the hilum and thence to the cardiac end of the greater curvature of the omach forming the anterior layer of the gastro-splenic ligament. Here it covers ıe antero-superior surface of the stomach and the commencement of the duodenum nd proceeds upwards from the lesser curvature of the stomach as the anterior layer f the lesser omentum.

(b) Traced further to the right the peritoneum winds round the bile duct, epatic artery and the portal vein and covers them from behind and crossing further o the left it proceeds upwards along the lesser curvature of the stomach as the osterior layer of the lesser omentum. Then it covers the postero-inferior surface of he stomach and passes to the hilum of the spleen as the posterior layer of the gastro-plenic ligament. Then it passes to the medial part of the anterior layer of the ieno-renal ligament and then passes across the posterior abdominal wall crossing he aorta and finally reaches the front of the inferior vena cava from where we tarted.

Epiploic Foramen or aditus to the lesser sac—(Foramen of Winslow). It is bounded *ı front* by the free margin of the lesser omentum containing the bile duct, hepatic rtery and the portal vein.

Behind by peritoneum covering the inferior vena cava.

Above by peritoneum on the caudate process of the liver and *below* by the peri-toneum covering the first part of the duodenum.

Below the level of the transverse colon in the lower abdomen:

Beginning from the middle line and traced to the right it lines the anterior abdominal wall and then passes to the sides of the caecum and the ascending colon and invests them from the sides and in front and then it passes towards the vertebral column covering the psoas major muscle and the inferior vena cava. Then it covers the mesenteric vessels and the small intestine from in front and behind and completes the formation of the mesentery and from its attachment to the vertebral column it passes to the left covering the left psoas major and the antero-lateral surfaces of descending colon and finally reaches the anterior abdominal wall from where we started.

In the Pelvis:

In the male it encircles the pelvic colon and is reflected on to the posterior wall forming pelvic mesocolon. Lower down in the pelvis it covers the rectum from in front and at the sides, where a fossa, the pararectal fossa, is seen on either side of the rectum. Then further lower down it covers only the front of the rectum and is reflected on to the bladder covering the upper end of the seminal vesicles. Between

the rectum and the bladder the peritoneal pouch is known as the rectovesical excavation. It is bounded laterally by the peritoneal folds which extend from the sides of the bladder to the sides of the rectum and the sacrum. These folds are called the *rectovesical folds* or *sacrogenital folds*. The peritoneum then passes upwards covering the superior surface of the bladder on to the anterior abdominal wall. On either side of the bladder, specially when it is distended, a fossa called *paravesical fossa*, is bounded laterally by a fold of peritoneum covering the vas deferens. When the bladder is empty a transverse fold of peritoneum, the *plica vesicalis*, transversely divides the paravesical fossa into two portions. Between the paravesical and pararectal fossae is an elevation produced by the ureters and the hypogastric arteries.

In the female the paravesical and pararectal fossae are also seen. The paravesical fossa is bounded laterally by a fold of peritoneum covering the round ligament of the uterus. The rectovesical excavation is divided by the uterus into shallow vesico-uterine, and deep, recto-uterine excavations bounded laterally by sacrogenital folds. From either side of the uterus the broad ligament passes laterally containing the uterine tubes in their free margins and subdivides the pelvic cavity into anterior and posterior compartments.

The ovaries are attached to the posterior part of the broad ligament by the mesovarium. In the lateral pelvic wall behind the attachment of the broad ligament, in the angle between the diverging hypogastric and external iliac arteries is a shallow depression—the *ovarian fossa* for the lodgement of the ovary.

PERITONEAL CAVITY

Normally both the visceral and the parietal peritoneum lie in close apposition with each other and the potential space between the two is known as the *peritoneal cavity*. When the abdomen is opened by dividing the parietal peritoneum on the anterior abdominal wall, the peritoneal cavity becomes exposed. In cases of accumulation of fluid or gas in between the parietal and visceral peritoneum the potential space also becomes apparent.

The peritoneal cavity is a closed sac of peritoneum in the male but in the female the sac communicates with the exterior through the abdominal osteum (opening of the uterine tube in the peritoneal cavity), uterine tube, uterine cavity and vagina respectively. The cavity extends from the under-surface of the diaphragm above to the bottom of the pelvic cavity below and sends in a small deverticulum which lies behind the stomach and the adjoining structures. Thus the peritoneal cavity can be subdivided into a greater cavity, the *greater sac* and a lesser cavity, the *lesser sac*, both of which are continuous with each other through a bottle-neck communication, the *aditus to the lesser sac* or the *epiploic foramen*.

Greater sac. As soon as the abdomen is opened by dividing the parietal peritoneum on the anterior abdominal wall the greater sac becomes opened up and extends from the under-surface of the diaphragm above to the floor of the pelvic cavity below.

BOUNDARY:

Above. It is bounded by that portion of the parietal peritoneum which covers the under-surface of the diaphragm.

Below. It is bounded by that portion of the parietal peritoneum which covers the pelvic floor.

Anteriorly. It is bounded by the parietal peritoneum that lines the posterior aspect of the anterior abdominal wall.

Posteriorly. It is bounded partly by the visceral peritoneum covering the viscera on the posterior abdominal and pelvic walls and partly by the parietal peritoneum on the posterior abdominal and pelvic walls.

The greater sac may be divided into *superior* or *supra-colic compartment* and *inferior* or *infra-colic compartment* by the transverse colon, transverse mesocolon and the greater omentum.

Supra-colic compartment. It is bounded *above* by the under-surface of the diaphragm; *below* by the transverse colon and the greater omentum; *anteriorly*, by the posterior surface of the anterior abdominal wall, and *posteriorly*, by the lesser omentum, stomach and the gastro-splenic omentum. The supra-colic compartment may further be sub-divided into different sub-phrenic spaces which have been described under separate heads.

The viscera to be found in this part of the greater sac are the liver, stomach and the spleen; the pancreas also lies in this part of the abdominal cavity but it is located behind the stomach under cover of the lesser sac.

The supra-colic compartment communicates with the infra-colic compartment over the greater omentum and with the lesser sac through epiploic foramen.

N.B. In inflammatory conditions when the greater omentum becomes adherent with the posterior aspect of the anterior abdominal wall, the supra-colic compartment may become completely shut off from the infra-colic compartment.

Infra-colic compartment. It lies postero-inferior to the transverse colon and its mesocolon and is more extensive than the supra-colic compartment. It is divided into *upper right compartment* and *lower left compartment* by the attachment of the root of the mesentery which extends from the left side of the second lumbar vertebra to the right sacro-iliac articulation passing obliquely in front of the vertebral column. The lower left compartment is continued downwards into the pelvic cavity. The infra-colic compartment contains the small intestines being surrounded by the large intestine.

LESSER SAC OR THE OMENTAL BURSA

The lesser sac of peritoneum or the omental bursa is a recess of the greater sac and lies mostly behind the stomach although it extends beyond its limit. It is of irregular outline, and being situated mostly behind the stomach, it acts as a bursa for the same (stomach) facilitating its movement and thus it is alternatively called the *omental bursa.* The bottle-neck communication between it and the greater sac is called the *additus to the lesser sac* which is bounded in front by the right free border of the lesser omentum, behind by the inferior vena cava, above by the caudate process and below by the first portion of the duodenum.

Component parts. It consists of a vestibule and an upper and a lower recess.

The *vestibule* of the lesser sac is a narrow area within the lesser sac and lies immediately to the left of the aditus to the lesser sac. From the vestibule the cavity of the lesser sac spreads out irregularly into the upper and lower recesses. The *upper recess* ascends upwards behind the caudate lobe to reach the anterior aspect of the diaphragm. The *lower recess* descends downwards and to the left in front of the anterior aspect of the pancreas and behind the stomach towards the spleen.

Boundary. The lesser sac has anterior and posterior walls and four borders, right, left, upper and lower.

The *anterior wall* of the lesser sac is formed by the following in order from above downwards:

(1) Peritoneum covering the caudate lobe of the liver.
(2) Posterior layer of the lesser omentum.
(3) Peritoneum covering the postero-inferior surface of the stomach.

Beyond the greater curvature of the stomach the anterior wall extends to the left side, and is formed by the posterior layer of the gastro-splenic omentum.

(4) Posterior layer of the anterior sheet of the greater omentum.

The *posterior wall* of the lesser sac, when traced from below upwards, is formed by the anterior layer of the posterior sheet of the greater omentum upto the anterior

border of the pancreas and then the posterior wall is formed by the peritoneum covering the anterior surface of the pancreas, part of the anterior aspect of the left kidney, most of the left suprarenal gland, commencement of the abdominal aorta the coeliac artery with its branches; finally the peritoneum covers the under-surface of the diaphragm and then is reflected on to caudate lobe of the liver to become continuous with the peritoneum forming the anterior wall of the lesser sac.

Left border It is formed by the left margin of the greater omentum, the gastro-splenic omentum and by the lieno-renal ligament.

Right border. The lower part of the right border is formed by the right margin of the greater omentum, by the peritoneal reflection from the head and neck of the pancreas to the under-surface of the first part of the duodenum; above the duodenum the border is interrupted by the presence of the epiploic foramen and the peritoneum becomes continuous with the peritoneum on the posterior wall of the epiploic foramen where it covers the inferior vena cava and finally it is reflected on to the caudate lobe of the liver.

Upper border. It is comparatively narrow and is formed by the peritoneal reflection between the inferior vena cava and the oesophagus.

The *lower border* corresponds presumably to the lower border of the greater omentum, although, the lower border rises to a higher level due to adhesion and fusion between the layers of the greater omentum.

Surgical importance. Pus or blood may accumulate into the lesser sac due to perforation of the stomach or duodenum and intra-peritoneal abscess may thus be formed and may spread along its boundary lines. Occasionally hernial protrusion may occur into this space, particularly through its aditus.

OMENTUM. An Omentum is a double fold of peritoneum that connects the stomach with some other viscera; usually three omenta are recognised, lesser omentum connecting the stomach with the liver, greater omentum connecting the stomach with the transverse colon and the gastro-splenic omentum which connects the stomach with the spleen.

Lesser omentum. It is a double fold of peritoneum that connects the lesser curvature of the stomach and the adjoining part of the first portion of the duodenum (first one inch) to the porta hepatis and the fissure for the ligamentum venosum of the liver.

Attachments. Above it is attached to the liver and its line of attachment is 'L'-shaped, the horizontal limb being attached to the margins of the porta hepatis, and the vertical limb to the depth of the fissure for the ligamentum venosum. *Below* it is attached to the lesser curvature of the stomach and to the upper part of the first one inch of the first portion of the duodenum. The portion that extends from the liver to the first part of the duodenum is called the *hepato-duodenal ligament*.

Borders. It consists of upper, lower, right and left borders. Its upper border is attached to the margins of the porta hepatis, its lower border is curved and corresponds to its line of attachment to the lesser curvature of the stomach and the adjoining portion of the duodenum; its right border is short, thick and rounded and forms a free margin and makes the anterior boundary of the aditus to the lesser sac or epiploic foramen; its left border corresponds to its line of attachment to the depth of the fissure for the ligamentum venosum.

Constituent peritoneal layers. It consists of two layers, anterior, and posterior. The anterior layer belongs to the peritoneum of the greater sac while the posterior one is formed by the peritoneum of the lesser sac. Both the anterior and the posterior layers are continuous with each other around the right border of the lesser omentum.

Contents:

(1) Right and left gastric arteries together with the corresponding veins —along the lesser curvature of the stomach.

(2) Portal vein, common bile duct and the hepatic artery—along the right free border of the lesser omentum. Of these the common bile duct lies to the right, the hepatic artery together with hepatic plexus of sympathetic to the left and the portal vein lies in between and behind them.
(3) Superior pancreatico-doudenal vein—lies close to the free margin of the lesser omentum at a plane anterior to all the structures enclosed by the lesser omentum in this situation.
(4) Lymph vessels, lymph glands and loose areolar tissue.
(5) Filaments from the anterior gastric nerve (left vagus) which pass to the liver.

Greater omentum. It is a large sheet of moveable peritoneal fold that hangs down from the greater curvature of the stomach and serves as an apron in front of the coils of the small intestine for a variable extent.

Form, extent and position. It is irregularly quadrangular in form and descends from the greater curvature of the stomach and the adjoining portion of the duodenum (first one inch) as a double layer and is folded on itself after a variable course, and then ascends upwards lying posterior to and in close apposition with the descending layers to the transverse colon and after enclosing the same it becomes continuous with the mesocolon. Thus the greater omentum can be divisible into four layers which are grouped into two sheets, two folds in each sheet, *anterior or descending* sheet and *posterior or ascending sheet.*

The downward extent of the greater omentum varies from subject to subject. In some it is seen to be much elongated to cover the small intestines completely; in some it is found to be too short while in some others it covers the small intestines only partially. In the child it is much shorter in extent because it has still to grow to attain its full adult size; *in position* it is also variable. Normally it lies in front of the small intestines as an apron but it may be found to be tucked in between the coils of the small intestine or into the left hypochondrium.

Constituent peritoneal layers. It consists of four layers of peritoneum, two in the descending sheet and two in the ascending sheet. The anterior layer of the descending sheet belongs to the peritoneum of the greater sac while its posterior layer is formed by the peritoneum of the lesser sac. The anterior layer of the ascending sheet is derived from the peritoneum of the lesser sac while its posterior layer belongs to the peritoneum of the greater sac. In between the ascending and the descending sheets is a potential space which forms the lower part of the lesser sac.

Characteristic feature. The greater omentum contains an enormous quantities of fat which are distributed in fatty islands having translucent fat free windows in between them. It may also be irregularly fenestrated. The other characteristic feature of the greater omentum is the presence of 'milk spots' which are patchy, whitish, dense oval areas on its surface and are formed by aggregation of *histiocytes*, a variety of fixed macrophages.

Contents. Besides large quantities of fat the anterior or the descending sheet of the greater omentum contains, in between its layers, about a fingers breadth below the greater curvature of the stomach, the anastomosis formed by the right and left gastroepiploic arteries, their omental branches and the accompanying veins, and the lymphatics and the lymph nodes draining the greater curvature of the stomach.

Functions:

(1) *Reservoir of fat.*
(2) It is an *adjustable packing material* which fills up spaces produced temporarily within the abdomen with movements of the body and the intestines.
(3) By localising inflammatory processes it serves as a *barrier against spread of infection.*
(4) *Defensive function.* The fixed macrophages of the 'milk spots' may be converted into wandering macrophages and thus they come into local and general body defences.

Surgical importance. It has been found that the greater omentum always moves to the place of trouble within the abdomen and hence it has been rightly termed by Rutherford Morison as the '*abdominal policeman*'. In appendicitis and other inflammatory conditions the greater omentum comes round the affected place and helps in localising the inflammation. In children, the greater omentum being too small to make the localising barrier, the chances of spread of infection in appendicitis and other intra-abdominal inflammatory conditions are more common and hence operative treatment is so often indicated in cases of appendicitis of the children.

Gastro-splenic omentum. It forms a short fold of peritoneum which connects the fundus of the stomach to the gastric surface of the spleen in front of its hilum. It is continuous below with the anterior sheet of the greater omentum and consists of anterior and posterior layers. The anterior layer is derived from the peritoneum of the greater sac while its posterior layer is formed by the peritoneum of the lesser sac. In between its layers it contains the short gastric branches of the splenic artery and some lymph nodes and lymphatics.

Peritoneal ligaments. A peritoneal ligament is a fold of peritoneum that connects any viscera to the abdominal or pelvic parieties or to some other viscera or to the diaphragm. The peritoneal ligaments are the following and have been described in appropriate places:

(1) Lieno-renal ligament.
(2) Gastro-phrenic ligament.
(3) Phrenico-colic ligament.
(4) Falciform ligament.
(5) Coronary ligament.
(6) Right and left triangular ligaments.
(7) Hepato-duodenal ligament.
(8) False ligaments of the urinary bladder.
  (a) Two posterior.
  (b) Two lateral.
  (c) Superior.
(9) Broad ligament of the uterus.

Mesenteries. The mesenteries are the double folds of *visceral peritoneum* which connect the different portions of the intestines with the posterior abdominal wall. They consist of mesentery proper, transverse mesocolon, pelvic mesocolon, mesentery of the vermiform appendix and sometimes ascending and descending mesocolons.

Mesentery proper. It is a broad fan-shaped fold of visceral peritoneum that connects the jejunum and ileum with the posterior abdominal wall. It consists of two folds of peritoneum derived from the peritoneum of the greater sac and invests the jejunum and ileum. It consists of an attached border and a free border. The attached border or the root of the mesentery is 6 inches in length and is attached to the posterior abdominal wall opposite to a line which begins from the left side of the second lumbar vertebra, passes obliquely across the vertebral column and then ends opposite the right sacroiliac articulation. Its free border corresponds to the free border of the jejunum and ileum and measures about 21 feet in length. The mesentery suspends the jejunum and ileum from the posterior abdominal wall and is broader below than above. It contains between its two layers, the jejunum and ileum, the jejunal and ileal branches of the superior mesenteric artery, mesenteric lymph nodes, mesenteric plexus of nerves, lymphatics and some fat.

Transverse mesocolon: Vide transverse colon.

Pelvic mesocolon: Vide Pelvic colon.

The mesentery of the vermiform appendix: It is a triangular fold of peritoneum consisting of two layers which enclose the vermiform appendix. Its base is

tached to the back of the mesentery proper and its medial margin ends in a free ›rder which contains the appendicular vessels, lymphatics, nerves and a lymph ›de.

Ascending and Descending mesocolons: Sometimes the ascending and :scending colon, instead of being covered only in front and at the sides by the perito- :um, are completely invested and loosely attached to abdominal wall by a mesocolon. he left colic flexure is attached to the diaphragm by a fold of peritoneum called ıe phrenico-colic ligament (opposite the 10th and 11th ribs) or the mesentery of ıe left colic flexure. It is also called the sustentaculum lienis as it supports the spleen.

Appendices Epiploicae. They are pedunculated pouches of peritoneum attached to ıe colon and upper part of rectum, containing fat and form the characteristic features ' the large intestine.

eritoneal Recesses or Fossae:

Duodenal Fossae:

(1) *Inferior duodenal fossa.* It is situated opposite to the third lumbar vertebra ı the left of the ascending portion of duodenum. The fossa has its cavity looking pwards and passes behind the duodenum. This is bounded by a fold of peritoneum, ith a concave margin called the inferior duodenal fold.

(2) *Superior duodenal fossa.* Its cavity looks downwards and is situated opposite ıe second lumbar vertebra to the left of the ascending part of the duodenum. Be- ind it, is a cresentic fold of peritoneum, the superior duodenal fold.

(3) *Duodeno-jejunal fossa.* It is bounded above by the pancreas, to the right by ıe abdominal aorta, and to the left by the kidney and behind by the left renal vein. .s cavity is directed downwards and to the right and admits the tip of the little nger. It may be absent altogether.

(4) *Paraduodenal recess.* It is situated a little to the left of the ascending part of ıe duodenum and is covered by a fold of peritoneum known as the paraduodenal ›ld whose concave margin is directed to the right. The paraduodenal fold contains ıe inferior mesenteric vein.

(5) *Retro-duodenal recess or fossa.* It intervenes between the front of the abdo- ıinal aorta and the third part of the duodenum. It is the largest of the duodenal :cesses and it is inconstant in its presence. Its opening is directed downwards and ›metimes it is large enough to extend upto the duodeno-jejunal flexure.

ubphrenic intraperitoneal recesses:

(*a*) *Right anterior intraperitoneal recess.* This is the space between the anterior urface of the right lobe of the liver and the diaphragm. It is bounded in front by the iaphragm and the anterior abdominal wall, behind by the anterior surface of right ›be of the liver, superiorly by the superior layer of the coronary ligament; inferiorly his space is open to the general peritoneal cavity; to the left by the falciform liga- ıent and to the right it is continuous with the right posterior intraperitoneal compart- ıent.

(*b*) *Right posterior intraperitoneal compartment.* It is bounded in front by the nferior and the right surfaces of the liver, behind by the peritoneum covering the liaphragm and the anterior aspect of the right kidney, above by the inferior layer ıf the coronary ligament; below this space is continuous with the general peritoneal :avity.

(*c*) *Left anterior intraperitoneal compartment.* It is bounded in front by the dia- ›hragm and the anterior abdominal wall, behind by the anterior surface of the left obe of the liver; below and to the left this space is open to the general peritoneal :avity; to the right it is bounded by the falciform ligament.

(*d*) *Left posterior intraperitoneal compartment.* This is the space formed by the esser sac of peritoneum and mainly lies behind the stomach. It communicates vith the greater sac through the aditus to the lesser sac.

Caecal recesses or fossae:

(1) *Superior ileo-caecal recess.* It is situated between the terminal part of the ileum and the commencement of ascending colon. It is bounded in front by a fold of peritoneum, the vascular fold of the caecum or the superior ileo-caecal fold, formed by the anterior caecal artery, behind by the mesentery proper, on the right side by the ascending colon and below by the terminal end of the ileum.

(2) *Inferior ileo-caecal recess.* It intervenes between the terminal portion of the ileum and the caecum. It is bounded above by the terminal portion of the ileum and the mesentery, below and in front by the inferior ileo-caecal fold and behind by the upper part of the mesentery of the vermiform appendix.

(3) *Caecal Fossa.* It lies behind the caecum. It is bounded on the right side by the caecal fold which extends from the lower part of the kidney to the right iliac fossa. Sometimes it may extend upwards behind the ascending colon and may contain the vermiform appendix in rare cases.

Intersigmoid Fossa It is situated to the left of the pelvic colon between the parietal peritoneum behind and the pelvic mesocolon in front. It lies in the interval between the psoas major and the iliacus muscles and on the external iliac vessels. This fossa varies in size, and is a constant feature in the foetus and infancy, and tends to disappear in advanced age when it is represented by a dimple in the situation.

FOLDS OF PERITONEUM IN THE PELVIS

Rectovesical excavation. In case of male the peritoneal fold after covering the front and the sides of the rectum is reflected on the superior surface of the urinary bladder forming a deep recess or pouch known as the recto-vesical excavation and the peritoneal fold covering the same is known as the recto-vesical fold of peritoneum.

Recto-uterine excavation. In females the peritoneal fold from the rectum is reflected on the posterior wall of the vagina and then to the cervix uteri and the body of the uterus forming a deep pouch or recess known as the recto-uterine pouch or the *pouch of Douglas.*

Vesico-uterine excavation. From the junction of the anterior surface of the body of the uterus with its cervix the peritoneum is reflected on to the bladder forming a shallower pouch, the *utro-vesical pouch.*

Broad ligament of the uterus. The fold of peritoneum that covers the front and back of the uterus, leaves the sides of the uterus as a double fold of peritoneum and extends to the side-wall of the pelvis as a broad fold known as the *broad ligament of the uterus.* In its course to the side-wall of the pelvis it encloses the uterine tube, round ligament of the uterus, ligament of the ovary and the uterine and the ovarian blood vessels in between its two layers.

Nerve supply of the peritoneum (Sensory): The peritoneum covering the central portion of the diaphragm is supplied by the phrenic nerve (C. 3, 4,5) and mechanical stimulation to this area causes referred pain to the shoulder through the third and the fourth cervical nerves (supraclavicular). The peritoneum covering the peripheral portion of the diaphragm is supplied by the lower six intercostal nerve and stimulation of this area causes referred pains in the anterior abdominal wall along the distribution of the intercostal nerves. The rest of the parietal peritoneum is also supplied by the lower six intercostal nerves and by the first lumbar nerve. The visceral peritoneum is insensitive but the different mesenteries are sensitive to pulling or dragging and probably derive their sensory fibres from the lower six intercostal and the first lumbar nerves. The greater and the lesser omenta are insensitive.

N.B. Peritoneal recesses are the frequent sites of abscess formation, particularly the subphrenic recesses. The collection of pus or fluid may be localised in any of these recesses or it may spread along their boundary lines. In some rare cases internal hernia may occur into some of these peritoneal recesses.

THE STOMACH

The stomach is the most dilated part of the digestive tube and occupies a recess the abdominal cavity bounded on the right side by the under-surface of the liver, the left side by the under-surface of the diaphragm, behind by the posterior dominal wall and anteriorly by the posterior surface of the anterior abdominal ıll. It lies opposite to the *epigastric*, *left hypochondriac* and part of the *umbilical region* the *abdomen*. It communicates above with the oesophagus and below with the st portion of the duodenum.

Measurements:

Maximum length—10 inches.
Maximum breadth—4 inches.
Maximum depth—$3\frac{3}{4}$ inches.

Capacity:

It varies from $2\frac{1}{2}$ to $2\frac{3}{4}$ pints (more in Indian subjects).

Parts for examinations:

(1) Two orifices—cardiac and pyloric.
(2) Two curvatures—*lesser* and *greater curvatures.*
(3) Two incisurae—incisura cardiaca and incisura angularis.
(4) A *fundus.*
(5) A *body.*
(6) A *pyloric portion.*
(7) Two surfaces—*antero-superior* and *postero-inferior*

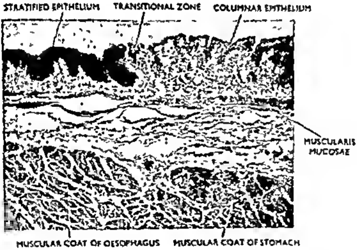


Fig. 703. The histological structure of cardio-oesophageal junction (Microphotograph) slide sent by Dr. K. Banerjee, Ph.D.

Cardiac orifice. The cardiac orifice is situated about 1" to the left of the median ane, about 4" behind the left seventh costal cartilage and lies opposite the level of e body of the eleventh thoracic vertebra or opposite to the 9th thoracic spine and is rectly continuous with the lower end of the oesophagus. The right margin of the sophagus forms a continuous line with the lesser curvature of the stomach while its ft margin joins with the greater curvature at an acute angle termed the *cardiac tch.* It is related in front with the left lobe of the liver, behind with the aphragm, to the right with the oesophageal branch of the left gastric artery and ith the fundus of the stomach to the left side.

Pyloric orifice. The pyloric orifice lies about half an inch to the right of the median plane opposite the level of the first lumbar vertebra and communicates with the first portion of the duodenum.

A circular constriction on the external aspect known as the pyloric constriction marks the situation of the pyloric sphincter. In the recent state the pyloric constriction is in direct contact with the prepyloric vein that descends in front of it and acts as guide to its situation. It lies behind the quadrate lobe of the liver and in front of the neck of the pancreas.

Lesser curvature. The lesser curvature of the stomach extends between the cardiac and pyloric orifices and is a 'J'-shaped border. It consists of vertical and horizontal portions which meet at a point where it is marked by a deep notch, the *incisura angularis* which divides the stomach into right and left portions. Above, the vertical limb of the lesser curvature is continuous with the right border of the lower end of the oesophagus; it meets the left end of the horizontal part at the incisura angularis below. The horizontal part of the lesser curvature terminates at the pyloric constriction on the right side and is continuous with the upper border of the first portion of the duodenum.

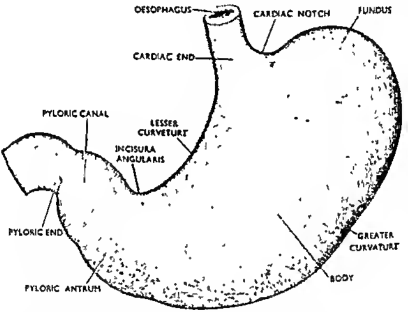


Fig. 704. The stomach (seen from the front). *From the dissection Hall, N.R. Sircar Medical College, Cal: with kind permission from Prof. of Anatomy.*

The lesser curvature of the stomach is overlapped by the liver and gives attachment to the lesser omentum and lodges the arterial arch formed by the right and the left gastric arteries with their accompanying veins and lymphatics.

Greater curvature. The greater curvature of the stomach is about 4 times longer than the lesser curvature and begins in the cardiac notch and ends at the pyloric constriction. It at first runs upwards, backwards and to the left to the level of the fifth intercostal space below the nipple and then runs downwards and to the right with a convexity to the left to reach the costal margin and crosses the costal arch between the 9th and the 10th ribs and finally passes across the abdomen to end into the pyloric constriction. In its course it forms two indentations, one being placed a little to the left of a line passing through the angular notch, and the other on the left side of the pyloric constriction. In between these two indentations it forms a bulging which is directed downwards. The greater curvature opposite the body of the stomach gives attachment to the greater omentum which connects it to the

ansverse colon and lodges the anastomosis formed by the right and left gastro-
iiploic arteries, and opposite the fundus, it gives attachment to the gastro-splenic
gament which connect it with the spleen.

Fundus. If a transverse line is passed across the lower end of the cardiac notch
ie portion of the stomach lying above this line constitutes the fundus of the stomach.

Pyloric portion. If a vertical line is passed through the angular notch, the portion
f the stomach on its right side upto the pyloric constriction constitutes the pyloric
ortion. It is divisible into *pyloric antrum* and *pyloric canal* by a notch on the
eater curvature situated in between the bulging and the pyloric constriction.
he pyloric constriction just succeeds the pyloric canal.

Body. The intervening portion of the stomach between the fundus and the
yloric portion forms the body of the stomach.

Antero-superior surface. The antero-superior surface of the stomach is more
onvex and is directed upwards and forwards. In most of the epigastric region it is
verlapped by the under-surface of the left lobe of the liver, and to a small extent,
y the right lobe. In the left hypochondriac region, its upper portion is in relation
ith the ribs, intercostal spaces and the diaphragm and is overlapped by the pleural
avity and base of the left lung being separated by the diaphragm; lower down in the
ft hypochondriac region, it is not overlapped by any viscera and is in direct relation
ith the sixth, seventh, eighth and ninth ribs with the intercostal spaces and the
iaphragm muscle. The area over which the antero-superior surface of the stomach
in direct relation with the chest wall is known as the *Traubes area.* It is a triangular
rea which is bounded above and to the right by the inferior border of the left lung,
elow and to the right by the left costal margin and posteriorly and to the left by the
pleen. Below and to the left in the epigastric and umbilical regions over a
iangular area, the *gastric triangle,* the antero-superior surface of the stomach comes
nto direct relation with the posterior surface of the anterior abdominal wall. This
astric triangle is bounded on the right side by the inferior border of the liver, on
he left side by the eighth and ninth costal cartilages and below by the transverse
olon. When the stomach is empty the transverse colon rides over the lower part of
he antero-superior surface of the stomach and thus may form an anterior relation to
t. Opposite the fundus of the stomach the gastric surface of the spleen forms an
dditional relation to this surface.

Postero-inferior surface. The postero-inferior surface of the stomach rests upon
ertain structures which form a shallow bed known as the *stomach bed.* The struc-
ures of the stomach bed are separated from the stomach by the lesser sac of the
eritoneum. They are as follows:

(1) Anterior surface of the pancreas.
(2) Anterior layer of the transverse mesocolon.
(3) Transverse colon (sometimes).
(4) Anterior surface of the left kidney.
(5) Anterior surface of the left suprarenal gland.
(6) Splenic vessels.
(7) Left crus of the diaphragm muscle.

Peritoneal relation. The stomach is entirely covered by the peritoneum except along the greater and lesser curvatures and over a small triangular area behind the cardiac orifice where it is directly is contact with the diaphragm. The layer of peritoneum that covers the antero-superior surface is derived from the peritoneum of the greater sac while that covers the postero-inferior surface is derived from the peritoneum of the lesser sac. The peritoneum from the two surfaces of the stomach meet together both at the lesser as well as at the greater curvature. The double fold of peritoneum from the lesser curvature passes to the liver forming the hepato-gastric part of the lesser omentum. The double fold of peritoneum from the greater curvature forms the greater omentum, gastro-splenic and gastro-phrenic ligaments.

Ligaments of the stomach. (All peritoneal).

(1) *Lesser omentum.* It connects the lesser curvature of the stomach with the porta hepatis and the fissure for the ligamentum venosum. It consists of two layers containing the right and left gastric arteries, portal vein, bile duct and the hepatic artery in between its two layers.

(2) *Gastro-phrenic ligament.* It is a double fold of peritoneum which connects the cardiac end of the stomach on the left of the oesophagus with the left crus of the diaphragm.

(3) *Gastro-splenic ligament.* It connects the fundus of the stomach to the spleen containing the short gastric and the left gastro-epiploic vessels in between its two layers.

(4) *Greater omentum* (gastro-colic). It connects the greater curvature of the stomach with the transverse colon containing in between its two layers the right and left gastro-epiploic arteries (All the ligaments of the stomach are peritoneal in origin).

Artery supply of the stomach :

(1) Right gastric branch of the hepatic artery.
(2) Right gastro-epiploic branch of the gastro-duodenal.
(3) Short gastric and left gastro-epiploic branches of the splenic artery.
(4) Left gastric branch of the coeliac artery.

Lymphatics of the stomach. The lymphatics of the stomach consist of three main sets of lymphatic plexuses—sub-mucous, muscular and subserous, which are connected to each other by lymph vessels. The origin and arrangement of these lymph vessels within the stomach are as follows:

The lymphatics of the stomach begin as *blind sub-epithelial lymphatic radicles* which unite into a fine *periglandular lymphatic plexus.* From the periglandular plexus lymph vessels pierce the muscularis mucosa and join the *sub-mucous lymphatic plexus,* the efferents from which pass through the muscular coat, anastomose freely to form the *intramuscular lymphatic plexus* from where lymph vessels come out of the muscular coat to join with the *sub-serous lymphatic plexus. Collecting vessels* from the sub-serous lymphatic plexus accompany the arteries of the stomach and are distributed to their corresponding group of lymph nodes in the following ways:

(1) Some of the lymphatics follow the course of the left gastric artery and they receive tributaries draining considerable areas on both the surfaces of the stomach and terminate in the left gastric group of lymph nodes.

(2) Some lymphatics drain the fundus of the stomach and the part of the body which lie on the left side of a line drawn vertically downwards from the cardiac end of the stomach, and accompanying the short gastric and the left gastro-epiploic arteries they terminate in the pancreatico-splenic group of lymph nodes.

(3) Some lymph vessels drain the right part of the greater curvature upto the pyloric end and accompanying the right gastro-epiploic artery they end into the right gastro-epiploic group of lymph nodes, the efferents from where pass to the pyloric group of lymph nodes.

(4) The lymphatics draining the pyloric portion pass into three directions—some join with the pyloric, some with the left gastric and the rest with the hepatic group of lymph nodes.

The efferents from all these nodes go to the coeliac group of preaortic lymph nodes.

The lymph vessels of the stomach, at its cardiac end, are continuous with the lymphatics of the oesophagus but at the pyloric end they rarely communicate with lymphatics of the duodenum, because of the presence of the connective tissue septum in the sub-mucous coat of the pyloric sphincter, absence of continuity of the circular muscle fibres and indipping of the longitudinal muscle fibres. The lymphatics of the stomach are provided with valves and the flow of the lymph passes from the left

art of the stomach towards the greater curvature and from the right part of the tomach towards the lesser curvature.

Nerve supply. The nerves of the stomach are derived from coeliac plexus of ympathetics and from both the vagus nerves. The fibres from the vagus nerve supply ecreto-motor fibres to the gastric glands, motor fibres to its musculature but inibitory fibres to the pyloric sphincter which receives its motor fibres from the ympathetics. The sympathetic fibres supplying the stomach are derived from the ixth, seventh, eighth and ninth thoracic segments of the spinal cord and are inibitory in function except in case of pylorie and eardiac sphincters where it is accelaory in function. Pains arising out from the stomach have the same segmental listribution on the skin through the intercostal nerves, i.e., the pain is distributed long the sixth, seventh, eighth and ninth intercostal nerves.

Structure of the stomach. Structurally the stomach consists of serous, ub-serous, muscular, sub-mucous and mucous coats.

The *serous coat* is formed by the peritoneum and it covers the stomach everywhere xcept the greater and the lesser curvatures, and a small area over the posteronferior surface of the stomach close to its cardiac end.

In the *sub-serous layer* there lies the prepyloric vein in front of the pylorus.

The *muscular coat* of the stomach is formed by plain or non-striated muscle ibres and consists of outer longitudinal, inner oblique and an intermediate circular ibres. The longitudinal fibres are eontinuous above with the longitudinal fibres of the oesophagus, and inferiorly, majority of them join in the pyloric sphincter and few only are continuous with the longitudinal fibres of the duodenum. The ircular fibres line the inner aspect of the longitudinal fibres and they are specially hickened opposite the pyloric constriction to form the pyloric sphincter. The circular ibres of the stomach are continuous with the circular fibres of the oesophagus out they are not continuous with the circular fibres of the duodenum from which hey are separated by a band of connective tissue septum. The oblique fibres lie nternal to the circular fibres and form 'U'-shaped loop round the fundus and the body.

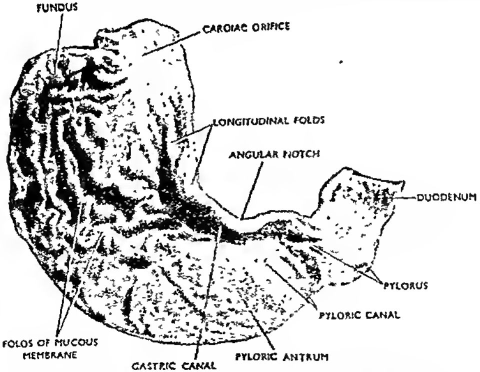
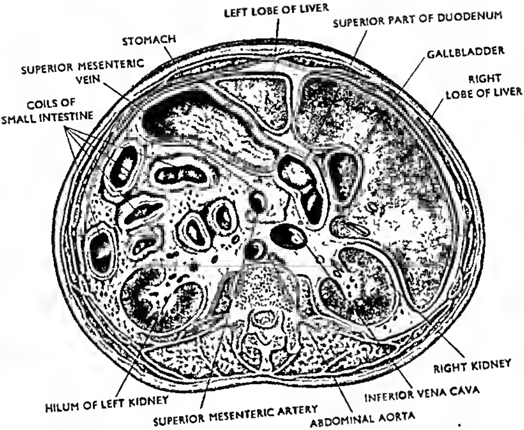


Fig. 705. The interior of the stomach (Photograph). From the dissection Hall, R.G. Kar Medical College, Cal: with kind permission from Prof. of Anatomy.



A transverse section of the abdomen opposite the seoond lumbar vertebra. With kind permission from: Lederle Laboratorise Ltd. Drawn by Mr. Paul Peck.

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Mucous fluid. The mucous secreted by the cardiac and the pyloric glands prevent autodigestion of the stomach.

Absorption. Small quantities of water, glucose, alcohol and some drugs, such as quinine, are absorbed from the mucous membrane of the stomach.

Elimination. Some toxins (toxins in uraemia) and some alkaloids, such as morphine, are eliminated through the mucous membrane of the stomach (that is the reason why the stomach-wash is done as a routine procedure in opium poisoning).

Hormonal functions. The mucous membrane of the pyloric portion secretes (1) a hormone-like substance known as the *gastrin* which acts as a stimulant for the second phase of gastric secretion. (2) The gastric juice contains an unknown factor known as the *castles intrinsic factor* which combines with the *extrinsic factor* present in the food to form the *haematinic principle* concerned in haemopoisis.

Protective reflex function. Irritation of the stomach causes salivation (through gastro-salivary reflex). Thus large quantities of saliva may be swallowed which help in reducing the irritation.

Secretory reflex function. The presence of food in the stomach reflexly stimulates pancreatic secretion.

The gastro-ilial and the gastro-colic reflex functions. These are passage-clearing reflexes through which about an hour after ingestion of food, there is increased peristalsis of the distal ileum and there is mass peristalsis of the large intestine.

Movements of the stomach. The movements of the stomach are dependent on the contraction of its muscular wall and on the movement of respiration and are called intrinsic and extrinsic movements respectively.

Intrinsic movements. The intrinsic movements of the stomach depend on the internal state of the stomach and vary in empty condition and after a meal.

In empty condition. The stomach is seen to possess two types of movements, *tonus rhythm* and *hunger contractions*. In *tonus rhythm* there is rhythmic variation of tone in a given time whereas in *hunger contractions* strong contractions involving the whole stomach occur at intervals. Such contractions usually last for about 30 seconds.

After a meal. As observed after a barium meal under the X-rays, the stomach is seen to possess three types of intrinsic movements, the *peristaltic movement*, *tonic contraction* and *active relaxation*. The right and the left halves of the stomach behave differently in their movements; whereas the body and the fundus show tonic contractions, the pyloric portion shows peristaltic movement which starts as a contriction wave at the region of the incisura angularis and then proceed towards the pylorus and recur at the rate of 3 or 4 contraction-waves in a minute. It may also show active relaxation in which the whole stomach is involved.

Extrinsic movement. It is a concertina-like movement in which the fundus is depressed whereas the pyloric portion is raised with each respiratory movement.

Development.—The stomach develops from the fore-gut as a continuation of the oesophagus. It forms a localised fusiform dilatation beyond which the fore-gut opens into the yolk sac. Later on, the opening of communication to the yolk sac becomes narrower and narrower in the median plane and remains attached to the posterior wall by dorsal mesogastrium. Then its left margin rapidly increases to form the fundus and the greater curvature, and in the meantime, the liver formed from the duodenal diverticulum, pushes the stomach to the left side and this results in rotation of the stomach to the right and consequently the duodenum comes to lie on the posterior abdominal wall.

Radiology. Normally the stomach is transparent to the X-rays but it can be made visible after ingestion of a radio-opaque meal such as the aqueous suspension of barium sulphate. After a radio-opaque meal the passage of the meal through the stomach can be directly visualized through fluoroscopy (looking through the X-ray screen) and it can also be palpated to determine its internal condition. A series of X-ray-photographs may also be taken to determine the form, filling, emptying and movements of the stomach.

Form of the stomach. Depending on the positions of the orifices and the borders of the stomach the radiological form of the stomach varies from individual to individual and in the same individual in different postures of the body. The *oesophageal orifice is stationary* because it is more or less fixed by the diaphragm. The position of the greater curvature of the stomach varies greatly from individual to individual in normal persons and it also varies in the same individual in different postures of the body. Thus in erect posture it occupies a level which varies between first lumbar and first sacral vertebrae and when supine, between twelfth thoracic and fifth lumbar vertebrae. On an average the *normal stomach is* 'J'-shaped with the angular notch lying on the same level with the iliac crests. In *hyposthenic subjects* the angular notch may be placed much below the above level—*long* 'J'-shaped. In *hypersthenic subjects* it may be of *short* 'J'-shaped form with the angular notch lying above the level of the iliac crests. In some individuals it may occupy a high horizontal position giving rise to the '*steerhorn*' *type of stomach.* In each case the fundus is filled up with gas giving a black shadow in contrast to the white shadow of the barium meal.

Filling and emptying. Normally the stomach is filled-up quickly with the ingestion of the meal. Depending on the nature of the food it takes about two to four hours in emptying.

THE LIVER

The liver is the largest gland in the body and is much larger in infants than in adults. It is *reddish-brown in colour* and roughly *triangular in shape* with the apex directed to the left and its base to the right side. It is soft and pliant to the touch and is of friable consistence.

Situation. It occupies the whole of the right hypochondriac region, and the greater part of the epigastric region. Sometimes it may even extend to the left hypochondriac region.

Size and weight. In male the liver is slightly larger and weighs a little more than that in the famale. In infants, it constitutes about one-eighteenth of the body weight, while in adults, it weighs about one thirty-sixth of the body weight.

Antero-posterior	6 inches.
Vertical	6-7 inches.
Transverse	6 inches.
Weight	3-3½ lbs. in males. 2¾ to 3 lbs. in females.

Parts for examinations. It consists of five surfaces and four lobes. The surfaces are *anterior, posterior, superior, inferior* and *right.* It consists mainly of two lobes—*right* and *left* but the right lobe is further subdivided into *quadrate* and *caudate* lobes.

Except the inferior margin, which is sharp and prominent and which separates the inferior surface from the anterior and right surfaces, there is no clear-cut demarcation of the surfaces which are continuous with one another by rounded borders. When the surface anatomy of the liver is undertaken its general form is taken into consideration and it is outlined by three margins, namely, superior, inferior and right margins.

Although it is customary to describe five surfaces, properly speaking, it has only wo surfaces, namely, *perietal* and *visceral.*

The PARIETAL SURFACE is moulded into the concavity of the diaphragm and according to the position it occupies the parietal surface may be divided into superior, anterior, posterior and right surfaces.

The *superior surface* fits under the vault of the diaphragm and is saddle-shaped being convex on each side and concave in the middle. This concavity on the superior surface is known as the *cardiac impression* which is separated from the diaphragmatic surface of the heart by the diaphragm and the pericardium. On each side, the superior surface is separated from the base of the corresponding lung by the diaphragm and the pleura.

The *anterior surface* is more extensive and is triangular in form. On the right side the intervening diaphragm separates this surface from sixth to the tenth ribs and the parietal pleura, and on the left side, from the seventh and eighth rib cartilages. Opposite the median plane, it is related to the back of the xiphoid precess, and below the infracostal angle, the anterior surface is related to the posterior surface of the anterior abdominal wall.

The *right surface* is divided into upper, middle and lower-thirds. The intervening diaphragm separates the upper-third, from the right lung and pleura, the middle-third, from the *costo-diaphragmatic racess of the pleura* and the lower-third, from the costal arches. It lies against the seventh to the eleventh ribs being separated from them by the diaphragm.

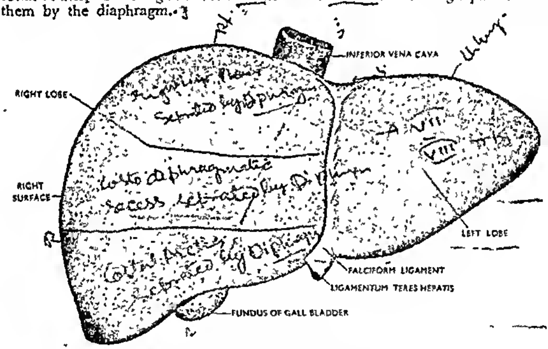


Fig. 706. The liver (seen from the front). (Diagrammatic).

The *posterior surface* is large and is mostly non-peritoneal. The large triangular non-peritoneal area on this surface is known as the *'bare area of the liver'* where the liver is adherent to the diaphragm by loose areolar tissue. The groove for the inferior vena cava containing the inferior vena cava forms the base of this area while the apex is formed by the right triangular ligament. In a separated liver, within the inferior vena cava, there are the openings of the *hapatic veins*. On the right side of the lower part of the groove for the inferior vena cava is a triangular depression for the right suprarenal gland (suprarenal area). The right crus of the diaphragm, the aortic opening in the diaphragm together with the descending aorta and the right phrenic artery come into intimate relation with this surface.

Inferior or *visceral surface of the liver.* The inferior or visceral surface of the liver occupies both the right and the left lobes of the liver and comes into intimate relation with the adjacent viscera. The inferior surface of the left lobe forms a shallow, wide

groove which is in relation to the antero-superior surface of the stomach (*gastric area*). On the right side of the gastric impression and opposite the left end of the porta hepatis is a rounded elevation known as the *omental tuberosity* which separates the lesser curvature of the stomach from the porta hepatis. The quadrate lobe comes

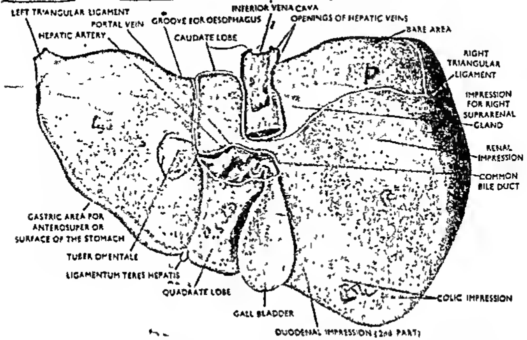
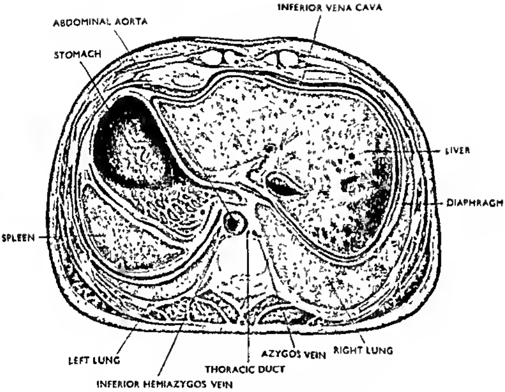


Fig. 707. The inferior surface of the liver.

into relation with the pyloric portion of the stomach and the first portion of the duodenum. On the right side of the quadrate lobe it is in relation to the superior surface of the gall bladder and constitutes the *fossa for the gall bladder*. Above and to the right of the fossa for the gall bladder it is in relation to the second portion of the duodenum (*duodenal area*). On the right side of the duodenal area the depressed area below is for the left colic flexure (*colic area*). To the right of the duodenal impression the hollowed out impression is for the anterior surface of the right kidney (*renal area*). A portion of the right suprarenal gland (*suprarenal area*) comes into relation with the inferior surface immediately above the renal impression. The *porta hepatis* which is a deep transverse fissure on the inferior surface of the right lobe, transmits the hepatic ducts, hepatic arteries and the branches of the portal vein in order from before backwards. The vertical deep fissure which separates the left lobe from the right lobe on the inferior surface, lodges the *ligamentum venosum* posteriorly and the *ligamentum teres* anteriorly. On the left side this fissure joins the porta hepatis at a right angle.

Lobes of the liver. *Anatomically* the liver consists of right and left lobes. The right lobe constitutes about ⅚ of the whole liver and contributes to form all its surfaces in parts (right surface wholly). The attachment of the falciform ligament on the anterior and superior surfaces demarcates the right from the left lobe of the liver, and inferiorly, the long vertical fissure caused by the ligamentum teres, et venosum separates the right from the left lobe of the liver. The deep transverse fissure on the inferior surface, the porta hepatis, further subdivides the right lobe into *caudate* and *quadrate* lobes. The caudate lobe lies posterior to the porta hepatis whereas the quadrate lobe lies anterior to it. Occasionally, particularly in ladies, a tongue-shaped process known as the *riedel lobe*, is seen to project downwards from the inferior border of the right lobe on the right side of the gall



A transverse section of the abdomen opposite the tenth inter-vertebral disc. With kind permission from: Lederle Laboratories Ltd. Drawn by Mr. Paul Peck. [To face page 861]

Physiologically and *developmentally* the liver is also subdivided into right and left lobes and the demarcation between the two is represented by an oblique line that passes upwards and to the left through the middle of the caudate lobe and the fossa for the gall bladder on the visceral surface of the liver. On the antero-superior surface a straight line that passes upwards from the apex of the gall bladder-notch to the point of junction between the left hepatic vein and the inferior vena cava, demarcates the two lobes: Each of these forms a functional lobe having one main biliary duct, that is, the hepatic duct, and has its own independent blood supply, the right lobe receives the right hepatic artery and the right branch of the portal vein and the left one receives the left hepatic artery and the left branch of the portal vein.

The CAUDATE LOBE is a rectangular projection of liver substance on the posterior part of the inferior surface of the liver with a tailing to the right from its right antero-inferior angle. It is interposed between the groove for the inferior vena cava on the right side and the fissure for the ligamentum venosum on the left side and is separated from the quadrate lobe by the porta hepatis. Its tailing to the right from its right antero-inferior angle forms a narrow elevation known as the *caudate process*, which connects it with the rest of the inferior surface of the right lobe of the liver. The caudate process separates the right part of the porta hepatis from the groove for the inferior vena cava. The left anterior-inferior angle of the caudate lobe forms a small rounded projection known as the *papillary process.*

The QUADRATE LOBE is quadrilateral in shape and is bounded in front by the inferior margin of the liver; behind by the porta hepatis, on the right by the fossa for the gall bladder and on the left by the fissure for the ligamentum teres. The quadrate lobe is in relation to the pyloric portion of the stomach.

The left lobe of the liver is much smaller than the right lobe and constitutes about $\frac{1}{6}$ of the whole liver. It is thinned out and flattened and comes to the formation of superior, inferior, anterior and posterior surfaces.

During the earlier part of development both the hepatic diverticula are of equal size but with the progress of development the left lobe becomes gradually smaller. In infancy the size of the left lobe is proportionately greater than that in the adult. The reduction in size of the left lobe is considered to be due to *proportionate reduction in its blood supply.* During foetal life blood from the left umbilical vein is by-passed into the inferior vena cava through the ductus venosus and that the portal vein joins the umbilical vein at an angle and these factors attribute to diminished blood supply to the left lobe which is inconsistent with the demand *required by its size and thus the left lobe becomes smaller. In the adult too the* left branch of the portal vein is seen to arise at an angle more acute than the right branch.

Nonperitoneal areas of the liver. The liver is everywhere covered by peritoneum except the porta hepatis, the fissure for the ligamentum teres and venosum, the fossa for the gall bladder, the groove for the inferior vena cava, the bare area of the liver and opposite to the line of attachments of the falciform, right and left triangular ligaments.

Bare area of the liver. The bare area of the liver is a large triangular area on the posterior surface of the right lobe of the liver and is devoid of peritoneal covering. It is in this area that the liver is dierectly connected to the under-surface of the diaphragm and they are bound together by loose connective tissue.

It lies in between the two layers of the coronary ligaments and is triangular in shape. Its base is formed by the groove for the inferior vena cava and theapex by the right triangular ligament. Its superior margin is formed by the superior layer of the coronary ligament while its inferior margin is formed by the inferior layer of the coronary ligament. The *portal vein and the systemic veins communicate in this area.*

Porta hepatis. The porta hepatis is the deep transverse fissure on the inferior surface of the right lobe of the liver through which the excretory ducts of the liver (right and left hepatic ducts) leave and the portal vein and the hepatic arteries enter

the substance of the liver. It extends from the neck of the gall bladder to the fissure for the ligamentum teres and measures about 2 inches in length.

The porta hepatis, which grooves transversely in the inferior surface of the right lobe of the liver, subdivides the right lobe into caudate and quadrate lobes.

Boundary. The porta hepatis is bounded in front by the quadrate lobe, behind by the caudate lobe, on the left side by the fissure for the ligamentum teres et venosum, and on the right side by neck of the gall bladder.

Relations. The porta hepatis is related to the lesser curvature of the stomach at its left extremity but is separated from the same by the tuber omentale and the fissure for the ligamentum teres et venosum. At its right extremity it is related to the neck of the gall bladder and the first portion of the duodenum. Posteriorly its right edge is separated from the inferior vena cava by the caudate process. The two lips or margins of the porta hepatis is connected with the lesser curvature of the stomach and the first portion of the duodenum by the lesser omentum. The lesser omentum being attached to its margins, the *bottom of the porta hepatis is devoid of peritoneal covering*.

Structure in the porta hepatis. The structures in the porta hepatis may conveniently be divided into (1) *Structures pertaining to the liver* and (2) *the structures pertaining to the gall bladder*.

(1) *Structures pertaining to the liver:*
- (a) Right and left hepatic ducts.
- (b) Right and left branches of the hepatic artery together with the hepatic plexus of nerves.
- (c) Right and left branches of the portal vein.
- (d) Paraumbilical vein.

(2) *Structures pertaining to the gall bladder:*
- (a) Cystic duct.
- (b) Cystic artery.
- (c) Cystic vein.

Relations of the structures in porta hepatis. The *right* and the *left* hepatic ducts emerge out of the corresponding lobe of the liver and appear at the anterior part of the porta hepatis close to its right edge and soon unite to form the *common hepatic duct*. The portal vein reaches the *posterior part* of the right end of the porta hepatis and divides into a long, left, and a short, right branch which enter into the corresponding lobe of the liver. The *cystic vein* accompanies the cystic duct and opens into the right lobe of the liver. The *paraumbilical vein* accompanies the ligamentum teres and opens into the anterior part of the left branch of the portal vein before it enters the left lobe. At the left end of the porta hepatis the left branch of the portal vein is joined by two fibrous bands, the ligamentum teres (obliterated umbilical vein) in front, and the ligamentum venosum (ducts venous which connect it with the inferior vena cava in foetal life) behind. The *right* and the *left branches of the hepatic artery enter the* corresponding lobe of the liver and intervene between the *hepatic ducts in front and the two branches of the portal vein* behind. The *cystic artery* arises from the right hepatic artery within the porta hepatis and passes beneath the neck of the gall bladder and the liver where it divides into superficial and deep branches. At the right edge of the porta hepatis the cystic duct begins as a direct continuation of the neck of the gall bladder and passes backwards and to the left to join with the common hepatic duct to form the *common bile duct* within in a short distance from the porta hepatis.

The hepatic arteries, the hepatic ducts and the two branches of the portal vein, as they are traced within the liver, are found to be enveloped by a thin areolar membrane known as the *hepato-billary capsule* or the *glisson's capsule*.

Ligaments of the liver. The ligaments of the liver consist of (1) peritoneal ligaments, and (2) fibrous bands which are embryonic remnants of the foetal circulation in the liver.

(1) PERITONEAL LIGAMENTS: (*a*) *Falciform ligament.* It is a short traingular fold of peritoneum consisting of two layers and connecting the anterior and the superior surfaces of the liver with the diaphragm and the anterior abdominal wall. It separates the right from the left lobe of the liver anteriorly.

(*b*) *Coronary ligament.* (superior and inferior layers). The superior layer of the coronary ligament is reflected to the upper and posterior surfaces of the liver from the diaphragm and is continuous with the right layer of the falciform ligament and covers the posterior part of the superior and superior part of the posterior surfaces and finally at the right side it is continuous with the anterior layer of the right triangular ligament, The inferior layer of the coronary ligament is continuous with the posterior layer of the right triangular ligament and passes horizontally along with the lower limit of the posterior surface of the right lobe below the lower end of the groove for the inferior vena cava and is then reflected to the right kidney to form the hepato-renal ligament. At its left extremity it is continuous with the peritoneal reflection at the right margin of the caudate lobe. The two layers of coronary ligament, as they diverge from the right triangular ligament, enclose the bare area of the liver.

(*c*) *Right triangular ligament.* It is formed by the fusion of the two layers of the coronary ligament opposite the upper part of the right surface and connects the liver with the diaphragm.

(*d*) *Left triangular ligament.* The left layer of the falciform ligament covers both aspects of the left lobe and opposite to the left extremity of the left lobe, the two layers are fused together to form the left triangular ligament which connects the liver with the diaphragm.

(*e*) *Hepato-gastric* and *hepato-duodenal ligaments.* (Lesser omentum). This is a double fold of peritoneum extending from the margins of the porta hepatis and the fissure for the ligamentum venosum to the lesser curvature of the stomach and to the upper border of the first portion of the duodenum.

(*f*) *Hepato-renal ligament.* It is formed by that fold of peritoneum which extends from the inferior layer of the coronary ligament to the front of the right suprarenal gland and the right kidney.

(2) FIBROUS LIGAMENTS OF THE LIVER: The fibrous ligaments of the liver are developmental vestigeal structures and consist of ligamentum teres and ligamentum venosum. (*a*) *Ligamentum Teres.* In foetal life the left umbilical vein joins with the left branch of the portal vein, and after birth, with the cessation of the foetal circulation it becomes oblitarated, and later on, forms the ligamentum teres which connects the liver with the anterior abdominal wall and is contained in the fissure for the ligamentum teres.

(*b*) *Ligamentum venosum.* This is the fibrous remnant of the ductus venosus, a large vein which carries blood from the left branch of the portal vein to the inferior vena cava in foetal life. It occupies the fissure for the ligamentum venosum.

The other vestigeal structure in connection with the liver is a fibrous band, formerly known as the *fibrous appendix of the liver,* and is situated at the left end of the left lobe of the liver. It represent the fibrous remnant of the more extensive left lobe of foetal life.

Circulation of blood in the liver. The liver receives oxygeneted blood from the right and left branches of the hepatic artery and (2) de-oxygenated blood carrying product of digestion from the right and left branches of the portal vein. Both the hepatic artery and the portal vein break up into minute branches within the liver and are accompanied by the branches of the hepatic duct. All these structures, as they bore into the substance of liver are accompanied by the hepato-biliary capsule and therefore are embeded in a connective tissue stroma. At the periphery of each liver lobule the minute branches of the portal vein are arranged in a plexiform network known as the *interlobular plexus* and to it the branches of the hepatic artery also join and the plexus is also accompanied by the minute branches

of the hepatic duct known as *biliary ductule.* The interlobular space together with the connective tissue stroma into which are embedded the interlobular plexus (formed by the minute branches of the portal vein and the hepatic artery) and the biliary ductule at the periphery of the lobule constitute the *portal canal.* Sinusoidal blood vessels from the interlobular plexus pass towards the centre of each lobule between two plates or laminae of hepatic cells (each plate being made up of single layer of hepatic cells) and drain into the *central vein.* The central veins from different lobules unite to form an *intercalated vein* (sub-lobular vein). The intercalated (sub-lobular) veins unite to form a *collecting vein* and the latter unite to form 2 or 3 hepatic veins, right, left and middle, which drain into inferior vena cava.

Section of the liver. A section of the liver presents the following differences between the portal and the hepatic veins.

Portal vein	*Hepatic vein*
Each branch of the portal vein is accompanied by a branch of the hepatic artery and a bile duct, all of which are surrounded by a capsule.	Are solitary veins and have no capsule.
Have stout walls.	Have delicate walls.
The walls of the vein are apposed to each other.	The walls of the vein being to the liver substance, the lumen of the vein is seen to be wide open.

Stability or the supports of the liver. Although the liver is about 3-4 lbs. in weight it does not fall down because of the following supports.

(1) Hepatic veins connect the liver with the inferior vena cava (most effective support) and support the *posterior heavier part* of the liver and the latter cannot fall down until the inferior vena cava is elongated.

(2) Ligamentum teres.
(3) Left triangular ligament.
} Support the the anterior part of the liver from falling down.

(4) Support from below by the stomach and the hepatic flexure.

Vascular supply of the liver. The liver gets its nutrition from two sources, from the hepatic artery and from the portal vein. The hepatic veins drain the liver to the inferior vena cava.

Nerve supply of the liver. It is supplied by the vagus nerves and by the hepatic plexus of sympathetic which derives its fibres from the seventh, eighth and ninth segments of the spinal cord.

Lymphatics the liver. Lymphatics draining the liver consist of *superficial* and *deep lymph vessels.*

The SUPERFICIAL LYMPH VESSELS lie beneath the peritoneum and have wide field of distribution. They may be subdivided into following sub-groups.

(1) *Lymphatics draining the adjoining portion of the falciform ligament.* Lymphatics draining the adjoining portion of the falciform ligament pass through this ligament and then piercing the diaphragm they end in the *anterior* group of supr phragmatic lymph nodes.

(2) *Lymphatics draining the left lobe.* Lymphatics from the upper part of parietal surface of the left lobe pass through the left triangular ligament and end in

the peri-oesophageal lymph nodes. Efferents from these lymph nodes terminate in the coeliac group of lympb nodes. Lymphatics from the anterior part of the parietal and from the inferior or visceral surfaces terminate in the *hepatic group of lymph nodes.*

(3) *Lymphatics draining the right lobe.* Those from the right surface and from the adjoining portion of the anterior surface pass through the right triangular ligament and piercing the diaphragm they end in the middle group of *supra-diaphragmatic lymph nodes.*

Those from the posterior surface pierce the diaphragm and terminate in *vena caval* group of *diaphragmatic lymph nodes* in the thorax. Lymphatics draining the superior, anterior and inferior surfaces of the right lobe end in the *hepatic group of lymph nodes.*

The **deep lymph vessels** drain the interior of the liver and they accompany the branches of the portal and the hepatic veins. Those accompanying the portal vein emerge at the porta hepatis and terminate in the *hepatic nodes.* Those accompanying the hepatic veins follow the inferior vena cava to the thorax where they end in the caval group of the *diaphragmatic lymph nodes.*

Histological structure. The liver is surrounded by a *connective tissue capsule* which is lined externally, in most of its parts, by a *serous lining,* the peritoneum. The smallest structural unit of the liver is a *hepatic lobule.* Each hepatic lobule appears as a polygonal prism measuring about 0.7 to 2 mm. in diameter. Surrounding each lobule (in man) is a poorly developed connective tissue stroma which forms the *perivascular fibrous capsule* into which are embedded the branches of portal vein, hepatic artery and a biliary ductule. The perilobular connective tissue stroma together with the vascular channels (portal vein and hepatic artery) and the biliary ductule constitutes the *portal canal.* From the portal canal sinusoidal blood vessels formed by the union of a branch from the portal vein and a branch from the hepatic artery enter, in series, into each hepatic lobule between the plates of hepatic cells and finally drain into the *central vein* within the centre of each lobule. The contiguous parts of three adjacent hepatic lobules which meet at the portal canal are drained by a common biliary ductule constituting a *portal lobule* and is represented by a triangle formed by the lines joining the central veins of these lobules.

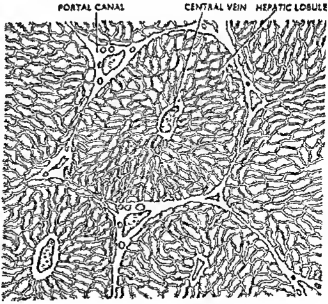


Fig. 708. The low power view of the histological structure of the liver. (Diagrammatic).

Hepatic lobule. Each hepatic lobule consists of a *central vein, irregularly radiating plates of hepatic cells* consisting of a single layer of cells, *sinusoidal blood vessels* which run between two plates of hepatic cells, a system of *biliary canaliculi,* a *limiting plate of liver cells* around the central vein and another ...nd the lobule in the region of the portal canal and another around the surfaces ...e liver.

Each *hepatic plate* is made up of a single layer of polygonal liver cells which radiate from the central vein to the periphery of the lobule; the plates are usually irregular

and they branch and communicate with adjacent plates or obules. In the space between two plates of hepatic cells, the *hepatic lacunae*, there lies the hepatic sinusoid which drains into the central vein after piercing the limiting plate around it. There is a potential space between the hepatic plate and the hepatic sinusoid and is called the *space of Disse* which is continuous with another potential space around the blood vessels and biliary ductule at the periphery of each lobule known as the *space of Mall*. In this space the lymphatics of the liver begin as a blind radicle.

Each *hepatic cell* is a large polygonal cell having six or more surfaces. It contains a vesicular nucleus with one or more nuclei and a few chromatin dots. Depending on the nature of the diet consumed by an individual, the cytoplasm of the hepatic cell shows variations in its fat, protein and glycogen content. The protein content of the cell is a ribonucleic acid which shows intense basophilic reaction. It also contains mitochondria, cytocentrum and Golgi apparatus like other cells.

The *hepatic sinusoid* is a large irregular vessel which is contained in the hepatic lacunae between two hepatic plates and drains its blood into the central vein; the sinusoidal vessel may branch and may communicate with the adjacent sinusoid by piercing the hepatic plates. Each is formed by a branch from the interlobular branch of the portal vein and is joined with branches from the hepatic arteries; the radicle of the interlobular branch of the portal vein which enters into the lobule by piercing the limiting plate of hepatic cells around the periphery of the lobule is

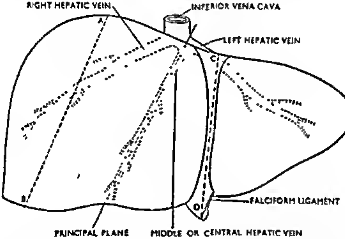


Fig. 709. The territory of the hepatic veins. Note the position of the principal plane which indicates the line of demarcation between the right and the left lobes. The dotted lines on the right and the left lobes indicate the possible lines of limited resection of the liver.

known as the *inlet venule*. The lining of the hepatic sinusoid forms a continuous sheet formed by two main types of cells, the un-differentiated lining cells, and the phagocytic stellate cells of Von Kupffer, connected together by numerous intermediate forms of cells.

The *biliary canaliculi* lie between opposing surfaces of the liver cells except opposite the sinusoidal vessels and converge towards the portal canal where they unite to form a biliary ductule.

Development. The liver is entodermal in origin and develops from the ventral diverticulum of the duodenum. In early embryonic life growth is not uniform in the diverticulum (ventral diverticulum) which soon bifurcates into two processes which are hollow processes in the beginning but soon they form solid masses, the *hepatic cylinders* which invade the under-surface of the septum transversum Later on, the two hepatic cylinders which ultimately form the right and left lobes o the liver, fuse together with the mesenchymal stroma embedded in it and later on

the liver is fully formed. The stalk of the ventral duodenal diverticulum forms the bile duct and from it solid cell outgrowth comes out which later on becomes hollowed and forms the gall bladder and the cystic duct, the stroma being formed by septum transversum.

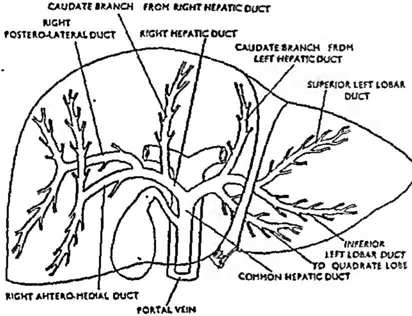


Fig. 710. The segmental anatomy of the liver.

Segmental Anatomy of the liver. *By injecting different aqueous coloured dyes through the hepatic ducts Hobsby in 1958 (British Surgical practice 1958) proved that each of the two principal lobes can further be subdivided into smaller independent segments each having its own biliary channels and vascular supply. The right lobe consists of two main segments, antero-medial and postero-lateral segments, and a small segment in the caudate lobe. Similarly the left lobe consists of two main segments, superior and inferior left lobar segments and two smaller segments, one for the caudate lobe and one for the quadrate lobe.*

THE EXCRETORY APPARATUS OF THE LIVER

The excretory apparatus of the liver consists of (1) the common *hepatic duct* formed by the union of the right and left hepatic ducts which emerge from the porta hepatis, (2) the *gall bladder* which serves as a reservoir for the bile, (3) the cystic duct and (4) the common bile duct, formed by the union of the common hepatic duct and the cystic duct.

THE GALL BLADDER

The gall bladder is a fibro-muscular hollow viscus in the biliary pathway, which acts as a specialised reservoir into which bile, secreted by the liver cells, is stored for concentration.

Shape and situation. The gall bladder is a *pear-shaped* hollow viscus lying on the inferior surface of the right lobe of the liver in a fossa extending from the right end of the porta hepatis to the inferior margin of the liver. The gall bladder is obliquely placed and its long axis is directed upwards, backwards and medially.

Parts for examination. It consists of a broad expanded blunt extremity called the *fundus* which in normal condition just peeps out from the inferior margin of the liver opposite to the tip of the right ninth costal cartilage. Just succeeding the fundus and gradually diminishing in diameter is the *body*, and the body is succeeded by the *neck* which is 'S'-shaped and is much diminished in calibre. From the neck of the gall bladder and continuous with it is the *cystic duct*.

Size and Capacity: Length 3 to ~~4~~ inches; *Breadth* 1½ inches; *Capacity* 1 to 1½ oz. Roughly 1 to 2 c.c. per kilogram of body weight).

Peritoneal relation. The fundus of the gall bladder is completely covered by peritoneum. The superior surface of the body and the neck is not covered by peritoneum and is adherent to the liver by some loose areolar tissue. Sometime the gall bladder is completely covered by peritoneum and is attached to the liver by means of a short mesentery.

General relations. The fundus of the gall bladder that extends beyond the inferior margin of the liver is in relation to the posterior surface of the anterior abdominal wall opposite to the tip of the right ninth costal cartilage and just approaches the angle between the costal arch and the lateral border of the rectus abdominis. Posteriorly the fundus is in relation to the transverse colon.

The *body* of the gall bladder is directed upwards, backwards and to the left from the fundus and its upper surface is adherent to the inferior surface of the liver by some loose areolar tissue. Its lower surface is in relation to the transverse colon and the first portion of the duodenum. To the right it is related to right colic flexure and the second portion of the duodenum. On the left side it is in relation with the pylorus and the first portion of the duodenum.

The *neck* of the gall bladder lies at a higher level than the fundus and is 'S'-shaped. It at first curves upwards and forwards and then abruptly backwards and downwards and is continuous with the cystic duct. It is attached to the under-surface of the liver by some loose areolar tissue and lies against the upper part of the free border of the lesser omentum. The cystic branch of the right hepatic artery lies in between the neck of the gall bladder and the liver where it divides into superficial and deep branches. The deep branch descends in between it and the liver while the superficial branch intervenes between it and its peritoneal covering. The cystic vein accompanies the neck of the gall bladder and ends by opening into the right branch of the portal vein. Between the junction of the body and the neck on the right side there is a small localised dilatation known as the *Hartman's pouch.*

The *cystic duct* measures about 3 to 4 cm. in length and it runs backwards, downwards and to the left from the neck of the gall bladder and joins the common hepatic duct on its right side at an acute angle, within ¼ inch from the upper border of the first portion of the duodenum and immediately below the porta hepatis to form the bile duct. Before joining with the common hepatic duct it runs in close contact with the latter for a short distance and is often adherent to it by connective tissue. Its mucous membrane is thrown into crescentic folds to form the *spiral valve* of the duct.

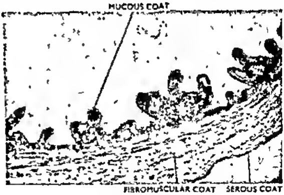


Fig. 711. The structure of the gall bladder. (Microphotograph).

Congenital anomalies. The solid diverticulum from the hollow ventral duodenal diverticulum (which forms the common bile duct) caudal to the hepatic buds from which the gall bladder and the cystic duct arise, may remain solid to form *solid gall bladder* and *solid cystic duct*. Occasionally the diverticulum for the gall bladder may bifurcate to form a forked *gall bladder*. The Hartman's pouch may also assume considerable size to resemble double gall bladder. It may be attached to the liver, or to the duodenum or to the colon by a mesentery. Anomalies of the duct system may also occur and are commoner and have been described under "variation in the formation of the common bile duct."

Histological structure. The gall bladder consists of a serous, perimuscular, muscular and a mucous coat in order from without inwards. The *serous coat*, formed by the

peritoneum, partially covers the gall bladder. The *perimuscular coat* is formed by a thick layer of connective tissue and embedded in it are blood vessels, nerves and lymphatics; opposite the fossa for the gall bladder it is continuous with the interlobular connective tissue of the liver. The *muscular coat* is formed by irregularly decussating smooth muscle fibres consisting of longitudinal, transverse and oblique fibres. The spaces between the muscular bands are occupied by collagenous, elastic and reticular fibres with a few fibroblasts. The *mucous membrane* of the gall bladder has a honey-comb appearance and is lined by a single layer of columnar epithelium and is absorbtive. It has no glands except in the neck where some small tubulo-alveolar types of glands are seen. The mucous membrane of the cystic duct is thrown into folds to form the *spiral valve of the duct.*

Occasionally, in the region of the neck and opposite the hepatic surface of the gall bladder, in the perimuscular coat, there may be seen some duct-like structures, the duct of Luschka, which have no connection with the lumen of the gall bladder. Some of these structures may be seen to indent into the muscular coat and some may be traced to connect with the bile duct. The ducts of Luschka are believed to be aberrant bile ducts which have been laid down during the process of development of the biliary system.

Occasionally the mucous membrane of the gall bladder is found to be evaginated in the form of small out-pouchings which extend through the lamina propria into the muscular layer. These out-pouchings are known as *Rolitansky—Aschoff sinuses.* These sinuses are believed to occur in pathological condition of the gall bladder in which its wall becomes sufficiently weak to permit such sinuses to develop.

Vascular supply. The gall bladder is supplied by the cystic artery, a branch of the right hepatic artery. It may occasionally be supplied, in addition, by an accessory cystic artery, a branch of the common or right or left hepatic artery. The gall bladder is drained by the cystic vein which opens into the right branch of the portal vein and by numerous small veins which pass into the liver and terminate into hepatic veins.

Nerve supply. The gall bladder is supplied by the sympathetic nerves and receives its fibres from the ninth thoracic segment of the spinal cord through the greater splanchnic nerve and the coeliac plexus. It also receives some filaments from the right phrenic and the vagus through the coeliac plexus.

Lymphatics of the gall bladder. The lymphatics draining the gall bladder pass between the two layers of the lesser omentum and terminate in the hepatic group of lymph nodes.

Function of the gall bladder. Acting as a reservoir, the gall bladder *concentrates* the bile and stores it from the liver via cystic duct in between meals when the sphincters of Oddi and of Boyden are in tonic contraction and discharge the concentrated bile into the second part of the duodenum via the common bile duct with meals.

Development. See development of the liver.

THE COMMON BILE DUCT

The common bile duct, as the name signifies, is a common tubular passage into which bile is discharged both from the liver through the common hepatic duct and from the gall bladder through the cystic duct and is conveyed to the second portion of the duodenum.

Formation. The common bile duct is usually formed within half an inch from upper border of the first portion of the duodenum immediately below the porta hepatis by the union of the common hepatic duct and the cystic duct. The cystic duct usually joins the common hepatic duct on its right side at an acute angle.

Variations in the mode of formation. (1) Frequently the common hepatic duct and the cystic duct run parallel to each other before joining to form the common duct.

(2) The union of the common hepatic duct and the cystic duct may take place either behind the duodenum or behind the head of the pancreas.

(3) The cystic duct may join the common hepatic duct either in front of or behind it or even on the left side of the common hepatic duct.

(4) The cystic duct may be absent and the common hepatic duct pierces the gall bladder and then emerges out of it as the main duct.

Measurements and direction. It measures about 3 to 4 inches in length and is of one-third to one-fourth inch in diameter. In abnormal cases the diameter may be much more than is normal and may even measure about one inch in diameter. Its general direction is downwards, backwards and to the left.

Course and relation. After its formation it runs downwards, backwards and to the left in front of the aditus to the lesser sac where it lies in the right border of the lesser omentum in front of the portal vein and on the right side of the hepatic artery (first part). It then passes behind the first portion of the duodenum to reach the head of the pancreas (second part). In this situation the gastro-duodenal artery lies on its left side. It then runs in a groove on the posterior aspect of the head of the pancreas (third part) and lies in front of the inferior vena cava and on the right side of the superior mesenteric vein. Next it passes along the medial border of the second part of the duodenum where it is crossed by the superior pancreatico-duodenal vessels and soon comes into contact with the pancreatic duct and the two ducts after piercing the duodenal wall separately unite together and form the ampulla of the duct. The distal constricted end of the ampulla ends by opening at the summit of the duodenal papilla situated about four inches from the pylorus and is usually hidden by a short fold of mucous membrane which constitutes its hood.

Variations in the mode of termination. (1) Instead of forming the ampulla after their union the two ducts may open independently into the ampulla. (2) The two ducts may open separately into the second portion of the duodenum (absence of union).

Nerve supply. The common bile duct is rich in its nerve supply which is distributed to its outer wall and fibres are derived from the vagi and sympathetics.

Structure. It is made up of a fibrous wall lined internally by a layer of columnar epithelium. Just before its termination into the second part of the duodenum it is encircled by a ring of muscle fibres which acts as a sphincter and is known as the *sphincter for the hepato-pancreatic ampulla* (sphincter Oddi). Another sphincter known as the *sphincter of Boyden* is situated immediately above its union with the pancreatic duct (the sphincter choledochus). Just before its joining with the common bile duct the pancreatic duct is also surrounded by a ring of circular muscle fibres in some cases and is known as the *Sphincter pancreaticus.* Besides the three above sphincters the *fasciculi longitudinales* consist of anterior and posterior longitudinal bundles which spread in the interval between the two ducts and extend from the margins of the fenestra of the ampulla.

An approach to the common bile duct. The abdominal cavity being opened, first of all, demarcate the transverse colon and trace it to its right extremity. Then detach the transverse colon from its adhesion to the head of the pancreas and the second part of the duodenum and then reflect it downwards. Then demarcate the lateral margin of the second portion of the duodenum and separate it from the front of the right kidney. Now carefully separate the rest of the duodenum together with the head of the pancreas from the renal vessels and the inferior vena cava and then together with the head of the pancreas turn over the duodenum towards the median plane. Now the bile duct is exposed which lies in a groove on the posterior aspect of the head of the pancreas and is crossed by the superior pancreatico-duodenal vessels in this situation. Traced upwards it is seen to pass behind the first portion of the duodenum with the gastro-duodenal artery on its left side and then it is contained in the free border of the lesser omentum where it lies in front of the portal vein and on the right side of the hepatic artery. Then trace it up to the porta hepatis and now it is completely exposed.

THE PANCREAS

Structurally the pancreas is an elongated *compound racemose gland* which resembles the salivary gland in sturcture and is of grayish-pink in colour. *Functionally* it is a *mixed type of gland* containing both exocrine and endocrine components.

Situation. It lies in the posterior abdominal wall behind the peritoneum, and extends obliquely upwards and to the left from the hollow of the duodenum to the spleen lying under cover of the stomach from which it is separated by the lesser sac. In position the pancreas occupies the epigastric and the left hypochondriac regions.

Measurements and weight. The pancreas varies in length from 5 to 6 inches (12-15 cm.) and is about half an inch in thickness. Its average weight is about 3 oz.

Parts for examinations. It is retort-shaped and the *bowl* of the retort, which lies at its right extremity, constitutes its *head*; succeeding the head is its *neck* which measures about ¾ inch. Its conical left extremity constitutes its *tail* and the intervening portion between its tail and the neck is its *body*.

Head of the Pancreas. The pancreas is retort-shaped and the bowl of the retort constitutes the head of the pancreas. The head is flattened from before backwards and its vertical diameter is larger than its transverse diameter. It is situated on the posterior wall of the abdomen opposite the level of the second lumbar vertebra and is received into the hollow of the 'C'-shaped duodenum. It is placed at a lower level than its tail which lies opposite the level of the first lumbar vertebra. The head of the pancreas sends out a process, the *uncinate process*, which projects from its lower part upwards and medially to intervene between the superior mesenteric artery and the abdominal aorta. The head is continuous with the neck on the left side and the demarcation between the head and the neck, anteriorly, is marked by a faint groove into which there lies the gastro-duodenal artery, and posteriorly, it is marked by a deep groove formed by the union of the superior mesenteric vein and the splenic vein to form the portal vein.

The head presents for examination two surfaces—anterior and posterior, four borders—superior, inferior, right and left and a process, the uncinate process.

Peritoneal relation. The anterior surface of the head of the pancreas is covered by the peritoneum below the area crossed by the transverse colon and the peritoneum is derived from the greater sac. The posterior surface and the uncinate process both are uncovered by peritoneum.

General relations. The *anterior surface* of the head is crossed by the transverse colon with which it is attached by some loose areolar tissue. Above the transverse colon, the anterior surface is overlapped by the first portion of the duodenum and below it, it is in relation with some coils of the small intestine. The *posterior* surface is in relation with the inferior vena cava, right crus of the diaphragm, terminal portion of the renal veins, and the common bile duct which may be embedded into the pancreatic substance. Close to its duodenal margin the common bile duct is crossed by the branches of the superior pancreatico-duodenal vessels and inferiorly it is related to the right testicular or ovarian vessels.

The *superior border* is overlapped by the first portion of the duodenum and is related to the hepatic branch of the coeliac artery. The *lower border*, from its left end, gives rise to the uncinate process and is in relation with the third part of the duodenum. Its *right border* fits into the concavity formed by the second portion of the duodenum, and in the groove between the two, the superior and the inferior pancreatico-duodenal arteries anastomose with each other and form two arches, one being placed anteriorly and the other posteriorly. The *left border* is very short and is in relation to the superior mesenteric vein.

The *uncinate process* is crossed in front by the superior mesenteric artery and intervenes between it and the abdominal aorta. The left renal vein is in close relation to its upper border.

The Neck of the pancreas measures about ¾" in width as well as in length and it is flattened from before backwards. It presents an anterior and a posterior surface

and an upper and a lower border. Between the head and the neck on the anterior surface there lies a faint groove which lodges the gastro-duodenal artery and marks the line of demarcation between the head and the neck; it is covered by the peritoneum of the lesser sac and is related to the pyloric portion of the stomach. The posterior surface is uncovered by peritoneum and comes into relation with the commencement of the portal vein which is formed in this situation by the union of the superior mesenteric vein and the splenic vein. The superior border is continuous with the superior border of the body and is related to the coeliac axis; the inferior border is continuous with the anterior border of the body.

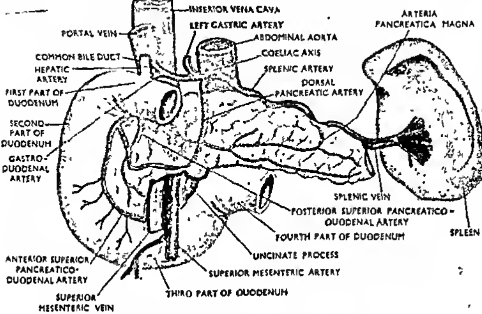


Fig. 712. The pancreas with blood vessels and the duodenum and the spleen.

The BODY of the pancreas is prismoid in shape and presents three surfaces—*anterior*, *posterior* and *inferior* and three borders—*anterior*, *superior* and *inferior*. The *anterior surface* lies in between the superior and the anterior borders and it is covered by the peritoneum of the lesser sac. It is in relation to the postero-inferior surface of the stomach and forms a part of the stomach bed. The *posterior surface* lies in between the superior and the inferior borders and it is usually grooved by the splenic artery which passes transversely from right to the left side. It is devoid of peritoneum. It is in relation, in order from right to the left, to the origin of the superior mesenteric artery, the left crus of the diaphragm, the inferior mesenteric vein, the left testicular or ovarian vein, the left suprarenal gland and the anterior surface of the left kidney. The inferior surface lies in between the anterior and the inferior borders and it is covered by the peritoneum of the greater sac. From right to the left it is in relation to the duodeno-jejunal flexure, some coils of the jejunum and the left colic flexure.

The *superior border* separates the anterior from the posterior surface and from its right end it gives out a process, the *tuber omentale* which comes into relation with the lesser curvature of the stomach. Superiorly it is related to the coeliac artery. The *anterior border* separates the anterior from the inferior surface and gives attachment to the two layers of the transverse mesocolon. The *inferior border* separates the inferior from the posterior surface, and close to its right extremity, it is closely related to the superior mesenteric artery.

TAIL. The tail of the pancreas succeeds the body and is formed by its left extremity which lies in contact with the medial surface of the spleen below the gastric impression and above the impression for the left colic flexure. It lies in

between the two layers of the lieno-renal ligament where it comes into close contact with the splenic vessels. Occasionally the splenic vessels cross in front of it on its way to the spleen.

Ducts of the pancreas. The exocrine secretion of the pancreas is conveyed to the duodenum by two ducts, one *main duct* which receives secretion from the tail, body, and part of the head, and an *accessory duct* draining the uncinate process and the lower part of the head. The main duct of the pancreas is usually known as the *pancreatic duct* and the other is known as the *accessory pancreatic duct*.

Pancreatic duct. It begins in the tail of the pancreas and traverses through the body lying midway between the superior and anterior borders and nearer to its posterior than its anterior surface. As it proceeds towards the head it gradually increases in its diameter and receives branches throughout it course which open into it almost at a right angle from both sides (Heiring-bone duct system). In the head it is about 3 mm. in diameter and turns downwards, backwards and to the right and comes into close relation with the bile duct which lies on its right side. Running side by side, the two ducts approach the medial wall of the second part of the duodenum which they pierce obliquely and running for a short distance within the wall of the duodenum, they unite together and then become dilated to form the *hepato-pancreatic ampulla* (*ampulla of the bile* duct.). The constricted distal end of the ampulla finally ends by opening into the summit of a *duodenal papilla* which is situated at a distance of about 8-10 cm. from the pylorus. Sometimes the two ducts open separately.

Accessory pancreatic duct. It is a small duct which drains the uncinate process and the lower part of the head and runs upwards to cross the pancreatic duct in front and is communicated to the latter by a branch at the neck of the pancreas. Then it passes almost horizontally, and by piercing the upper part of the medial wall of the second part of the duodenum, it ends by opening into the summit of a small papilla situated about 2 cm. above the duodenal papilla about 7 cm. from the pylorus and at a plane slightly anterior to the pancreatic duct.

N.B. The presence of two ducts of a single gland in the adult is due to the origin of the gland from two different primodia, the dorsal and the ventral pancreatic diverticula from the duodenum, in embryonic life (*see* development of pancreas). The accessory pancreatic duct is the duct of the dorsal pancreatic diverticulum whereas the main pancreatic duct is the duct of the ventral pancreatic diverticulum. The ventral pancreatic diverticulum arises from the stalk of the hepatic diverticulum (the future common bile duct) and also communicates with the stalk of the dorsal pancreatic diverticulum. Subsequently, the dorsal pancreatic diverticulum drains through the stalk of the ventral diverticulum and forms the main pancreatic duct and the ventral diverticulum drains through the accessory duct.

Artery supply. The head of the pancreas is supplied by the superior and inferior pancreatico-duodenal arteries. The *body* and the tail are supplied by the pancreatic branches of the gastro-duodenal, superior mesenteric and splenic arteries respectively. One of these arteries is comparatively large (arteria pancreatica magna) and courses from left to the right in company with the pancreatic duct.

N.B. The pancreas is a derivative of the fore-gut but its artery supply, though predominently derived from the artery of the fore-gut (coeliac artery), is also derived from the artery of the mid-gut (superior mesenteric artery). This is possibly due to the origin of the pancreatic diverticula from near the junctional zone between the fore-gut and the mid-gut.

The veins are corresponding to the arteries and finally end into the portal vein (pancreatic veins into splenic vein, inferior pancreatico-duodenal into sup. mesenteric and sup. pancreatico-duodenal into portal vein).

Lymphatics of the pancreas. The lymphaties draining the pancreas begin in the lymphatic cleft between the alveoli of the gland and they terminate in the coeliac nodes either directly or indirectly through the superior mesenteric or pancreatic group of lymph nodes.

Nerve supply of the pancreas. The pancreas is supplied by vagus and splanchnic nerves through splenic plexus.

Development. The pancreas arises from the dorsal and ventral diverticula; the ventral diverticulum arises from the stalk of the hepatic diverticulum whereas the dorsal one arises from the dorsal part of the duodenum cranial to the ventral one. Due to rotation of stomach and duodenum the two diverticula are approximated to each other and are fused to form a cell mass. The tail, body, neck and a part of the head are formed from the dorsal rudiment and the rest of the head is formed from the ventral rudiment. The ducts of the two rudiments freely communicate with each other.

Histological structure. The *exocrine portion* of the pancreas forms a lobulated mass formed by the fusion of different lobules and resembles the salivary glands structurally except that it has no capsules or has only indefinite capsule made up of loose areolar tissue. It consists of *duct systems* each member of which divide and subdivide into finer ramifications each of which terminates into an *alveolus*. The cells of the terminal ductule at their junction with those of the alveolar cells behave differently in their staining reaction (stain less deeply) and are called the *centro-acinar cells which are of cubical types*. The cells of the minute ducts connected with the alveoli are lined by flattened type of cells.

The *cells of the alveolus are of columnar type* and they are arranged into two zones, inner and outer. The cells of the outer zone lie on the basement membrane and are characterised by clear cytoplasm with faint striation. The cells of the inner zone contains granules in their cytoplasm (Trypsinogen).

The *endocrine portion* of the gland forms a syncytium of cells situated in between the alveoli and are known as the *interalveolar cell-islets or the islands of Langerhans*. They are *granular, polyhedral cells which are richly supplied by blood vessels*. In a zenker-formal fixed specimen stained with Mallory-azan stain three types of cells, A-cell, B-cell, and D-cell (alpha, beta, delta) whose granules stain differently can be identified. A-cells show brilliant red granules, B-cell, brown-orange granules whereas the D-cells show blue granules. The B-cells are alcohol soluble.

The interalveolar cell-islets are found throughout the whole pancreas but they are in abundance in the tail of the pancreas

THE SMALL INTESTINE

The small intestine constitutes the longest part of the digestive tube and extends from the pyloric end of the stomach to the ileocolic valve. It is about 22 feet in length and gradually diminishes in calibre from its commencement to its termination. Its walls are smooth and regular. It is divisible into three parts—*duodenum*, *jejunum* and *the ileum*. The first twelve inches constitute the duodenum which lies against the posterior abdominal wall and is devoid of any mesentery. Both the jejunum and ileum are suspended from the posterior abdominal wall by a broad fold of visceral peritoneum known as *the mesentery*. The jejunum forms about 2/5 whereas the ileum 3/5 of the remaining portion of the small intestine.

Duodenum. The duodenum is the most fixed portion of the small intestine and is devoid of any mesentery. The word duodenum is the latin corruption of Greak word 'Dodekadaktulos' meaning twelve fingers. This is so named bacause it measures about twelve fingers in length. While in situ, its course resembles the letter 'C' and in the hollow of the 'C'-shaped duodenum the head of the pancreas is having a close fittings.

IDENTIFICATION OF DUODENUM:

(1) Its wall is bile stained.
(2) It has no mesentery.
(3) Presence of the duodenal papilla in its interior.
(4) Circular mucous folds are exceedingly coarse and thickly set up.
(5) Bile duct pierces the medial wall of its second part.

COURSE OF DUODENUM. The duodenum begins from the pylorus opposite the level of the first lumbar vertebra and then passes upwards, backwards and to the right under cover of the quadrate lobe of the liver to the neck of the gall bladder forming the *first portion* of the duodenum and then makes a sudden bend (superior duodenal flexure) downwards and descends on the right side of the vertebral column as far as the lower border of the third lumbar vertebra constituting the *second* or the *descending portion* of the duodenum. It then makes another bend to the left (inferior

duodenal flexure) and passes horizontally across the vertebral column to reach the front of the abdominal aorta and forms the third or the *horizontal part of the duodenum.* The fourth part of the duodenum begins from opposite the front of the abdominal aorta and ascending upwards for about one-inch as far as the level of the second lumbar vertebra it ends into the duodeno-jejunal flexure. The first part of the duodenum measures about 2 inches, the second part 3 inches, the third part about 4 inches and the fourth part about one inch in length.

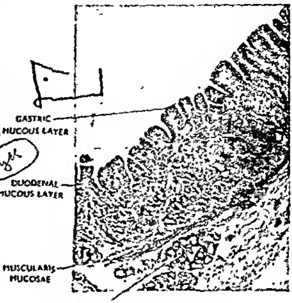


Fig. 713. Histological structure of gastro-duodenal junction (Microphotograph). Slide lent by Dr. K. Banerjee Ph D.

RELATIONS OF THE FIRST PART. The first part of the duodenum *ascends upwards, backwards* and to the right from the pylorus to the neck of the gall bladder. *Anteriorly* it is in relation with the gall bladder, *posteriorly* with the portal vein, common bile duct and the gastro-duodenal artery, *superiorly* with the aditus to the lesser sac and the quadrate lobe of the liver and *inferiorly* with of the pancreas. It is entirely covered by peritoneum anteriorly. Posteriorly *it is* not covered by

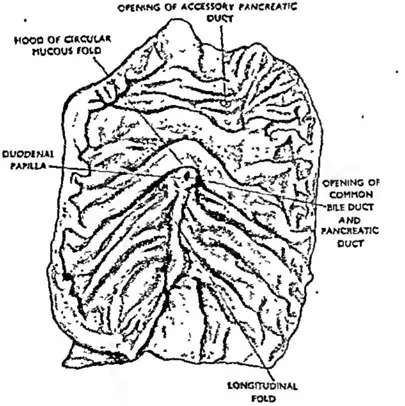


Fig. 714. The interior of the second part of the duodenum. From the dissection Hall, N. R. Sircar Medical College, Cal; with kind permission from Prof. of Anatomy.

peritoneum except close to the pylorus where it is covered by peritoneum and forms a small part in the anterior boundary of the lesser sac. The lesser omentum is attached to its upper border and the greater omentum to the proximal half of the lower border.

Relations of the second part. It begins from the level of the neck of the gall bladder and ends into the third part opposite the level of the third lumbar vertebra. *Anteriorly* it is crossed by the transverse colon to which it is adherent by some loose areolar tissue. Above the transverse colon it is in relation with the inferior surface of the liver, and below, with some coils of the small intestine. *Posteriorly* it is in relation with the anterior surface of the right kidney close to its hilum, the right renal vessels, right psoas major muscle and the right edge of the inferior vena cava. *Medially* it is in relation with the head of the pancreas and the common bile duct and the pancreatic ducts which unite to form the ampulla and the constricted end of the ampulla pierces its medial wall to open into the duodenal papilla about 4 inches from the pylorus. The accessory pancreatic duct, when it exists, opens into it about 3/4 inch proximal to the duodenal papilla. *Laterally* it is related to the right colic flexure. Anteriorly, both above and below the transverse colon, it is covered by peritoneum and posteriorly it is uncovered by peritoneum.

Relations of the third part. The third part of the duodenum begins from the level of the third lumbar vertebra and passing transversely across the vertebral column ends into the fourth part opposite the front of the abdominal aorta. *Anterirolу*, it is crossed by the superior mesenteric artery and the mesentery. *Posteriorly*, in its course from right to the left, it passes in front of the right ureter, right psoas major muscle, right testicular or ovarian vessels, inferior vena cava and the front of the abdominal aorta. *Superiorly* it is in relation to the head of the pancreas and *inferiorly* to some coils of the small intestine. Anteriorly it is every where covered by the peritoneum except where it is crossed by the superior mesenteric artery and the mesentery. Posteriorly it is not covered by peritoneum except close to its left extremity where over a small area it may be covered by the peritoneum.

Relations of the fourth part. It begins from opposite the front of the abdominal aorta and ascending upwards and to the left it ends at the duodeno-jejunal flexure to become continuous with the jejunum. *Anteriorly* it is in relation with the transverse mesocolon. *Posteriorly* it passes in front of the left psoas major muscle, left ovarian or testicular vessels and the left sympathetic trunk and the inferior mesenteric vessels. *Superiorly* it is related to the body of the pancreas. *Inferiorly* it is related to some coils of the small intestine. It is entirely covered by peritoneum.

Artery supply of the duodenum. The portion of the duodenum developed from the fore-gut, that is, that which lies above the opening of the common bile duct is supplied by supra-duodenal branch of gastro-dudenal or hepatic artery, retro-duodenal branch of the gastro-duodenal, by a branch from the right gastro-epiploic, and occasionally by a branch from the right gastric artery and by the superior pancreatico-duodenal branch of gastro-duodenal artery. The portion developed from the mid-gut, that is, that which lies below the opening of the common bile duct is supplied by the inferior pancreatico-duodenal branch of superior mesenteric artery. These two arteries (superior and inferior pancreatico-duodenal arteries) form two anastomosing arches, one in front of and the other behind the pancreatico-duodenal groove, from which vasa recta pass to the two walls of the duodenum.

Lymphatics of the duodenum. Lymphatics draining the duodenum are arranged into anterior and posterior sets of lymph vessels and they end respectively in the *anterior* and *posterior* groups of *pancreatico-duodenal lymph nodes*. These lymph nodes occupy the anterior and posterior aspects of the groove between the head of the pancreas and the duodenum. Efferents from these lymph nodes end in the hepatic and superior mesenteric group of lymph nodes.

Structure of the duodenum. (*Vide* structure of the jejunum and ileum It consists of (*a*) serous, (*b*) muscular, (*c*) sub-mucous and (*d*) mucous coats.

(*a*) *Serous coat.* Formed by peritoneum which partially covers the different portions of the duodenum.

(*b*) *Muscular coat.* Consists of outer longitudinal and inner circular muscle fibres.

(*c*) *Sub-mucous coats.* Contains blood vessels, lymph vessels and nerves and duodenal glands (Brunner's gland).

(*d*) *Mucous coat.* Are thrown into folds which are coarse and thickly set. *Mucous folds are absent in the first part of the duodenum.* The mucous folds of the duodenum are *permanent folds.*

Development. Both the stomach and the duodenum lie in the median plane with their dorsal mesentery being attached to the dorsal wall. Later on, when stomach rotates to the right the duodenum is also affected and comes to lie in the posterior abdominal wall beneath the peritoneum; subsequently a diverticulum is formed from its ventral part and from this diverticulum the liver develops and the stem of the diverticulum forms the common bile duct. Similar diverticula from its ventral and dorsal parts give rise to the formation of the pancreas. The portion of the duodenum as far as the opening of the common bile duct develops from the fore-gut whereas the rest of it develops from the mid-gut.

N.B. This being the most fixed portion of the small intestine it is the frequent seat of rupture due to external violence in the form of kick in the abdomen. The third part of the duodenum is most vulnerable because it is fixed in front of the vertebral column.

Jejunum and Ileum. The jejunum and the ileum constitute the longest portion of the digestive tube and measure about 21 feet in length. They are the

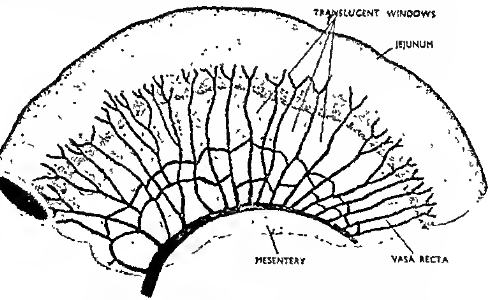


Fig. 715. The external features of the jejunum. From the dissection Hall, N. R. Sircar Medical College, Cal; with kind permission from Prof. of Anatomy.

most moveable part of the intestine and are suspended from the posterior abdominal wall by an expanded fold of peritoneum known as the mesentery. Their walls are smooth and regular.

Vascular supply of the jejunum and ileum. The arteries supplying the jejunum and ileum are the jejunal and ileal branches from the superior mesenteric artery respectively. The terminal portion of the ileum also receives some branches from the ileocolic artery.

The veins are corresponding to the arteries and they drain through the superior mesenteric vein to the portal vein. These veins are not provided with any valve.

Nerve supply of the jejunum and ileum. The nerves supplying the jejunum and ileum are the superior mesenteric plexus of sympathetics and the vagus nerve (Parasympathetics). The nerves arrange themselves in two ganglionated plexuses—one being situated in between the two muscular coats known as the *myenteric plexus* (Auerbach's plexus) and the other is situated in the sub-mucous coat and is known as *plexus of the sub-mucosa* (Meissner's plexus).

Lymphatics of the jejunum and the ileum. The lymphatics draining the jejunum and the ileum consist of sub-mucous, intramuscular and sub-serous lymph plexuses which all communicate with one another. The sub-mucous plexus receives the lymph vessels draining the mucous membrane and also receives the lacteals. Efferents from its plexus penetrate the muscular wall after joining with the intramuscular plexus and end in the sub-serous plexus. Collecting vessels from the sub-serous plexus pass between the two layers of the mesentery and after passing through the superior mesenteric lymph nodes they end in the cisterna chyli.

Structure of the jejunum and ileum. The wall of the jejunum and ileum is composed of serous, muscular, sub-mucous and mucous coats.

Serous coat. The serous coat is formed by the peritoneum which completely covers them from all sides except over a narrow space along their mesenteric border.

Muscular coat. The muscular coat consists of *outer longitudinal* and *inner circular fibres.* The outer longitudinal fibres are continuous with the similar fibres of the duodenum and the stomach. The inner circular fibres line the inner aspect of the longitudinal fibres and are continuous with the circular fibres of the duodenum. The circular fibres of the duodenum are separated from the circular fibres of the

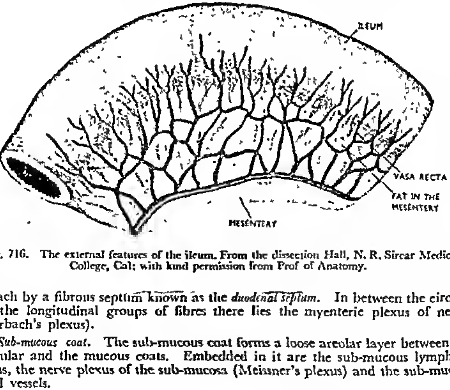


Fig. 716. The external features of the ileum. From the dissection Hall, N. R. Sircar Medical College, Cal; with kind permission from Prof of Anatomy.

stomach by a fibrous septum known as the *duodenal septum.* In between the circular and the longitudinal groups of fibres there lies the myenteric plexus of nerves (Auerbach's plexus).

Sub-mucous coat. The sub-mucous coat forms a loose areolar layer between the muscular and the mucous coats. Embedded in it are the sub-mucous lymphatic plexus, the nerve plexus of the sub-mucosa (Meissner's plexus) and the sub-mucous blood vessels.

Mucous coat. The mucous coat or the mucous membrane of the jejunum and ileum are thrown into folds which are *permanent folds* and cannot be effaced out of them during distention. They are transversely disposed across the lumen of the gut and each measures about 2 inches in length and 1/6 inch in breadth. Some of

hem form a complete circle around the lumen, some extend for about one-half to wo-thirds of its circumference, some are spirally arranged while some of them have one extremity bifurcated into two imbs. In the jejunum they are more numerous, closely set and thicker in consistency. In the ileum they are vide apart and in the lowest part of the ileum they are almost absent. On he deep aspect of the mucous membrane there is a layer of plain muscle ibres known as the *muscularis mucosa.* The mucous membrane of the jejunum and ileum are lined with a single ayer of columnar epithelium which s thicker in the jejunum than in the leum. Besides the circular folds, the nucous membrane presents the ollowing characteristics:

Fig. 717. The interior of the jejunum. From the dissection Hall, N. R. Sircar Medical College, Cal; with kind permission from Prof. of Anatomy.

(1) *Villi.* They are minute projections on the mucous surface having a velvety appearance and are closely set up all over the mucous membrane except over the solitary and aggregated lymph nodes. They are more abundant in the duodenum and jejunum and less so in the ileum. Structurally, each villis is covered by a single layer of columnar epithelium and is composed of (*a*) *a capillary network of blood vessels,* (*b*) *one or more lacteals,* (*c*) *adenoid tissue* and (*d*) *nerve-fibrils* from the Meissner's plexus.

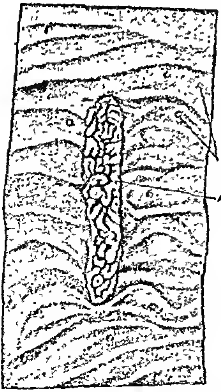


Fig. 718. The aggregated and solitary lymphatic nodules in the interior of the ileum. From the dissection Hall, N. R. Sircar Medical College, Cal; with kind permission from Prof. of Anatomy.

(2) *Intestinal glands.* They are abundantly present all over the small intestine and are alternately called the crypts of Leiberkeuhn. They resemble simple tubular gland and are *seen as small diverticula of the* mucous membrane.

(3) *Solitary nodules.* They form oval or rounded small elevations on the mucous membrane formed by lymphocytes. Their deeper ends project into the submucous coat.

(4) *Aggregated lymph nodules or Peyer's patches.* They are formed by the coalescence of some of the solitary nodules and form oval or round elevations on the mucous surface. They are placed along the free border (antimesenteric) of the small intestine and are found in the upper part of the ileum and in the lower part of the jejunum. The villi are deficient

over them and the circular mucous folds fail to extend over them. They are more numerous during infancy and childhood and only a few of them, numbering about thirty, are present in the adult. Comparatively they are more numerous in the ileum than in the jejunum. Each patch measures about 1 to 4 inches in length and about ½ to 1 inch in breadth. With advancing age they gradually fade away and in extreme old age they are merely represented by discoloured patches.

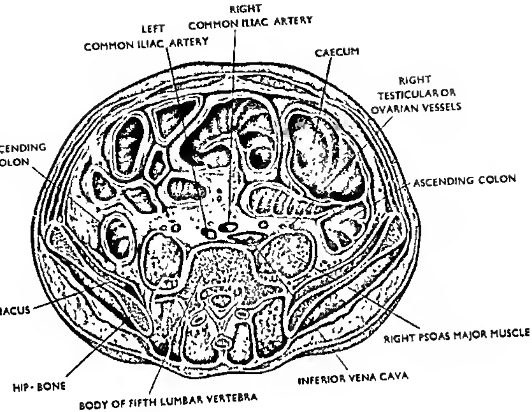
Differences between jejunum and ileum

Internal features	Jejunum	Ileum
Circular folds	Numerous; very distinct and lying close by.	Few, indistinct and wide apart and absent in the lower part.
Villi	Numerous; large	Less numerous and smaller.
Solitary lymph nodule	Innumerable.	Scanty.
Aggregated lymph nodule	Few, small and circular in outline.	More numerous; large and oval in outline.
External features		
Wall	Thicker.	Thinner.
Calibre	Wider.	Less wide.
Mode of blood supply	The arteries supplying the jejunum, before reaching it, form one or two arterial arches in the mesentery and from it straight arteries 1 inch long reach the gut.	The arteries, supplying the ileum, before reaching it, form two or three arterial arches in the mesentery from which straight vessels ½ an inch long reach the gut.
Distribution of the fat	Fat normally present in the mesentery fails to reach the jejunal wall and hence there are translucent windows in the mesentery at the edge of the jejunum.	Fat of the mesentery accompanying the vessels creeps on to the wall of the ileum and there is absence of translucent windows.

THE LARGE INTESTINE

The large intestine begins from the ileocolic valve and ends in the anal canal. It is much less in length than the small intestine and measures about 6 feet. In spite of its being smaller in length *it is called 'large' because it has the largest capacity to distend.* Its calibre is large and it is widest at its beginning and then gradually narrows to its termination. It is more or less fixed with limited range of movement. At its commencement it forms a pouch-like dilatation known as the *caecum* from the postero-medial aspect of which the vermiform appendix arises. From the upper end of the caecum the *ascending colon* begins and ends in the right colic flexure from where the *transverse colon* begins and passing transversely across the abdominal cavity, ends the left colic flexure. From the left colic flexure the *descending colon* begins and ends in the *pelvic colon* opposite the brim of the pelvis. The pelvic colon ends in the rectum opposite the third sacral vertebra and the rectum ends in *anal canal.* The large intestine presents the following distinctive features:

(1) Its walls are irregular and sacculated due to the disproportionate size between its mucous tube and its taenia. The mucous tube is 6 feet in length whereas the taenia are 4 feet in length and in order to accommodate the longer tube into the shorter taenia the walls of the large intestine are puckered and sacculated.



A transverse section of the abdomen opposite the fifth lumbar vertebra. With kind permission from: Lederle Laboratories Ltd. Drawn by Mr. Paul Peck.

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(2) Presence of the appendices epiploicae. These are small peritoneal pouches containing fat which hang from the wall of the large intestine except the vermiform appendix and the rectum.

(3) Presence of the taenia. Longitudinal muscle fibres of the large intestine do not form a continuous covering over the large intestine but they are grouped into distinct bands known as the *taeniae*.

(4) The large intestine is more or less fixed in position.

(5) The mucous membrane does not present any villi nor does it present any circular mucous folds and instead the folds are short and irregular.

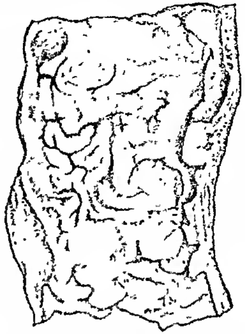


Fig. 719. The interior of the large intestine. From the dissection Hall, N. R. Sircar Medical College, Cal; with kind permission from Prof. of Anatomy.

Taenia coli. The longitudinal muscular fibres of the large intestine do not form a continuous covering over the large intestine but they are grouped into three distinct bundles known as taenia coli. Each taenia is about 4 feet long.

The taenia are three in number and according to their situation they are named as (1) taenia mesocolica—placed opposite the attached border of the intestine, that is, posteriorly, (2) Taenia omentalis—placed postero-laterally in case of ascending and descending colons and opposite the attachment of the greater omentum in case of transverse colon. (3) Taenia libera—placed anteriorly in the ascending and descending colons and along the under-surface of the transverse colon.

The taeniae coli serve as the indentity for the large intestine. It is present everywhere in the large intestine except the rectum and the vermiform appendix.

Appendices epiploicae. The appendices epiploicae are the small peritoneal pouches containing fat which hang from the wall of the large intestine. The fat accumulating in between the taeniae under the peritoneum protrudes from the wall of the large intestine as small pouches constituting the appendices epiploicae. They are present along the whole length of the large intestine except the vermiform appendix and the rectum. Hence it is evident that the appendices epiploicae will be found there where the taeniae are present and where the peritoneal covering is more or less complete. It is abundantly present in the transverse and pelvic colon.

The appendices epiploicae are the important features for the identification of the large intestine.

THE CAECUM

The caecum is a wide asymmetrical cul-de-sac furnished with the taeniae and together with the vermiform appendix forms the commencement of the large intestine. It is the most superficial part of the large intestine and is contained within the right iliac fossa and is formed by that portion of the large intestine which lies caudal to the entrance of the ileum. Opposite the ileocaecal junction there is a constriction which demarcates the caecum from the ascending colon. The caecum itself is also marked by a constriction which makes the caecum sacculated having a medial and a lateral bulge.

POSITION. It is usually situated in the right iliac fossa immediately above the lateral half of the inguinal ligament but sometimes it may be situated at a higher level in the lumbar region below the liver or lower down in the plevic cavity. The *apex* of the caecum is its caudalmost part and corresponds to a point that lies medial to the mid-point of the inguinal ligament.

Types or forms of the caecum. There are usually four types of caecum depending on its shape and form as described below:

Foetal or conical type. It is *conical in shape* and the vermiform appendix is attached to its apex and thus the latter lies along the long axis of the ascending colon. All the three taeniae converse to the base of the appendix and they are equidistant from each other. This is a normal condition in the foetus but this form may persist in the adult as well.

Quadrilateral type. In this the caecum is more quadrilateral in form and the appendix is found to be attached between two bulging sacculi. The taeniae maintain their relative position as above and converge to the base of the appendix.

Usual or adult type. This is the usual type of caecum found in the adult. In this type, the portion of the caecum that lies lateral to the taenia libera (anterior band) is wider and more bulging than the part medial to it due to disproportionate growth in the two walls of the caecum. The anterior wall is also more bulging than the posterior wall. The vermiform appendix is attached to the postero-medial wall of the caecum about 2 cm. below the terminal portion of the ileum.

In the *fourth type* the lateral wall of the caecum grows enormously whereas its medial wall atrophies and due to this the taenia libera is seen to converge to the caudal angle at junction of the ileum with the caecum and the base of the appendix is found to be attached to it behind this angle from opposite the ileocaecal junction.

Measurement. Length—2 inches; breadth—3 inches.

Comparative Anatomy. It varies considerably in its form amongst the various groups of mammals. In the herbivorous mammals it is much longer than those in the carnivorous. In anthropoid apes and in man it is much smaller in size and assumes a form in which its anterolateral wall grows out of proportion to its posteromedial wall.

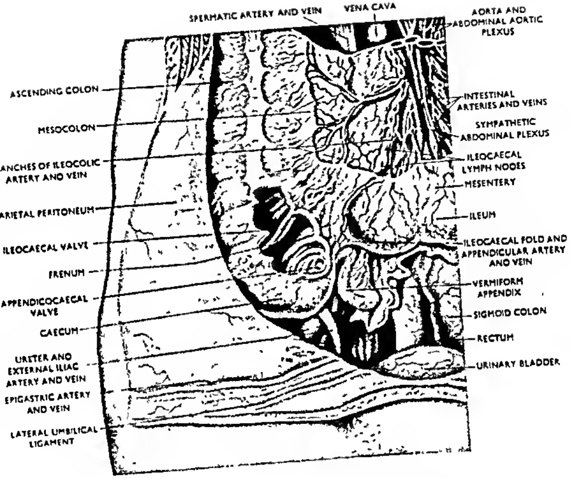
Peritoneal relation. Caecum is usually completely covered by peritoneum but in about 5 per cent of cases its posterior surface may be uncovered by peritoneum and may remain adherent to the fascia iliaca.

General relations. Posteriorly it rests upon the ilio-psoas muscle being separated from it by the fascia iliaca and the intervening lateral cutaneous nerve of the thigh. The femoral nerve comes into relation with this surface but is separated from it by the fascia iliaca and by some fibres of the psoas major muscle. The vermiform appendix is attached to its postero-medial wall about 2 cm. below the ileum. Superiorly it is continuous with the ascending colon. Inferiorly it rests upon the ilio-psoas muscle. Anteriorly it is in relation to the abdominal parieties.

Interior of the caecum. The terminal portion of the ileum opens into the postero-medial aspect of the caecum at its junction with the ascending colon and its opening is guarded by a valve consisting of two lips known as the *ileocolic valve.* It is placed at the junction of the caecum and ascending colon. It consists of two lips, upper and lower. The upper lip is attached between the ileum and the ascending colon while the lower lip is attached between the ileum and the caecum. From the point where the two lips unite a ridge-like mucous fold extends on the wall of the caecum on each side and is known as the *frenulum.*

It is formed by the reduplications of the mucous membrane and the circular muscular fibres of the ileum. Normally it is in a state of tonic contraction due to the impulses it receives from the sympathetics through the splanchnic nerves. Stimulation of the vagus causes relaxation of this sphincter.

Artery supply. It is supplied by the anterior and posterior caecal branches of the ileocolic artery. The veins are corresponding to the arteries.



A dissection of the interior of the caecum to show the ileocolic valve and the opening of the vermiform appendix. With kind permission from : Lederle Laboratories Ltd. Drawn by Mr. Paul Peck.

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Nerve supply. It is supplied by the vagus and sympathetic nerves.

Lymphatics. The lymphatics draining the anterior aspect of the caecum end in the anterior ileocolic and upper and lower ileocolic group of lymph nodes. Those draining the posterior aspect terminate in the posterior and inferior ileocolic group of lymph nodes.

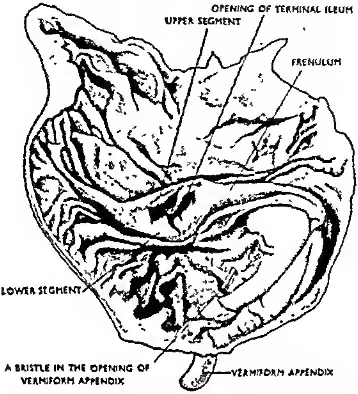


Fig. 720. The interior of the caecum. From the dissection Hall, N. R. Sircar Medical College, Cal; with kind permission from Prof. of Anatomy.

N.B. Since the contents of the caecum is fluid, neoplasm of the caecum rarely cause acute intestinal ›struction which is common in case of the other parts of the large intestine. In case of obstruction ' the large intestine ileo-caecal valve is competent enough to prevent regurgitation from the caecum › the ileum.

THE VERMIFORM APPENDIX

The vermiform appendix is a long worm-like structure situated on the postero-nedial aspect of the caecum at a distance of about 3/4 inch below the terminal ›ortion of the ileum and marks the commencement of the large gut. It is a narrow ubular structure attached to the caecum by a broad base and ends below into a apering free extremity. It is kinkled on itself so as to resemble an worm and ience the name 'Vermiform' has been applied to it. All the three taeniae of the irge intestine converge to the base of the vermiform appendix, the taenia libera if the caecum which is present on its anterior aspect is a guide to the vermiform ppendix.

At an early embryonic life it has the same calibre as the caecum and lies in the ame line with it but later on due to excessive growth of the right wall of the caecum, tubular recess is formed on its medial wall which forms the appendix.

Measurements:

Average length	3 inches.
Maximum length	9 inches.
Minimum length	1 inch.

Peritoneal relation. It is entirely covered by peritoneum and has a short mesentery, the mesenteriole of the appendix, which connects it with the mesentery of the small intestine. It forms a free border along which there lies the appendicular artery.

Positions of the vermiform appendix. From its attachment to the postero-medial aspect of the caecum, the tapering extremity of the vermiform appendix may be directed variously and the direction of the tip of the vermiform appendix indicates its different positions. Making the vermiform appendix as the pointer and the caecum as the dial of a clock, the various positions of the vermiform appendix have been summarised by Sir Frederick Treves as follows:

(1) 11 *O'clock position or para-colic or para-caecal.* In this the vermiform appendix is directed upwards and to the right and lies on the right side of the caecum. In this position it may lie either behind the peritoneum or may partially project into the peritoneal cavity and may lie in front of the right kidney.

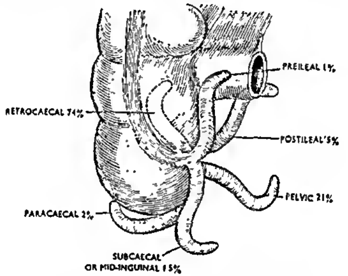


Fig. 721. The positions of the vermiform appendix

(2) 12 *O'clock position or retro-colic.* It lies either behind the caecum or the ascending colon and may lie behind the peritoneum or may have partial access to the peritoneal cavity.

(3) 2 *O'clock or splenic position or pre- or post-ileal.* It is directed towards the spleen and may pass either in front of or behind the terminal part of the ileum. In this position it lies completely within the peritoneal cavity.

(4) 3 *O'clock or promontoric.* The appendix is directed transversely inwards towards the sacral promontory.

(5) 4 *O'clock or pelvic position.* The appendix hangs over the brim of the pelvis and projects into the pelvic cavity. In case of female it may lie over the broad ligament or the ovary.

(6) 6 *O'clock or mid-inguinal.* In this the appendix passes downwards towards the middle of the inguinal ligament.

Anatomical structure. On transverse section it is found to contain a canal within, which communicates with the caecum by an orifice. The canal of the appendix is lined by mucous membrane which is continuous with the mucous membrane of the caecum. The mucous membrane is thrown into folds and near its orifice of communication with the caecum, the mucous folds are arranged in the form of a pair of valves which guards its orifice. Beneath the mucous membrane

there is a submucous layer which contains enormous lymphoid tissues for which it has often been called by the surgeons as the 'abdominal tonsil'. Outside the submucous coat is the muscular layer which consists of both longitudinal and circular fibres. Lining the muscular coat is the serous layer or the peritoneum. At certain places

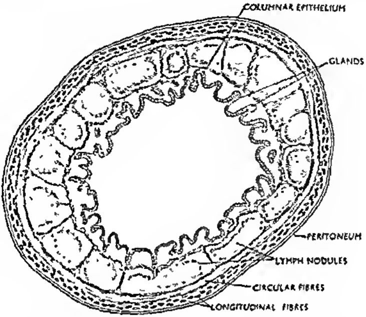


Fig. 722. The structure of the vermiform appendix (*Diagrammatic*).

both the circular and longitudinal fibres may be deficient and thus in those places the serous layer lies in direct contact with the submucous layer.

Artery supply. The appendicular branch of the ileocolic artery supplies the vermiform appendix. It is an end-artery and lies along the free border of its mesentery.

The veins open into the ileocolic veins.

Lymphatics. The lymphatics draining the vermiform appendix pass between the two layers of its mesentery and end in the ileocolic group of lymph nodes.

Surgical importance. It is the frequent seat of inflammation causing appendicitis. Due to its varying positions, in cases of appendicitis sometimes spontaneous spread of the inflammation to the general peritoneum is met with. Referred pain in appendicitis is first noticed in the epigastric or in the umbilical region and when its peritoneal covering is involved, the pain localise in the right iliac fossa and there is muscle-guarding.

THE ASCENDING COLON

Extent and course. It begins as a direct continuation of the caecum in the right iliac fossa, and ascending vertically upwards through the right lumbar region it ends in the right colic flexure at the inferior surface of the right lobe of the liver lateral to the gall bladder in the right hypochondriac region.

Length and calibre. In length it varies from 15 to 20 cm. and in calibre it is smaller than the caecum but wider than the descending colon. 6 to 8"

Peritoneal relation. The ascending colon is covered by peritoneum both in front and at the sides but it is uncovered by peritoneum posteriorly. In some cases it receives a complete investment from the peritoneum and acquires a short meso-

colon by which it is suspended from the posterior abdominal wall. A little above the transtubercular plane, occasionally, a fold of peritoneum extends laterally from the ascending colon and supports the liver from below and is often called the *sustentaculum hepatis*. In the region of the right colic flexure there are three inconstant peritoneal folds, one extending to the diaphragm, one to the liver and another to the gall bladder and are named as *phrenicolic, hepatocolic* and *cystocolic* folds respectively.

General relations. *Anteriorly*, it is related to some coils of the small intestine and to the right edge of the greater omentum which separates it from the posterior aspect of the anterior abdominal wall. *Posteriorly*, it is related to the iliacus muscle and the fascia iliaca, the iliolumbar ligament, the fascia covering the quadratus lumborum, the aponeurotic origin of the transversus abdominis and to the lower lateral part of the right kidney from which it is separated by the perirenal fascia. The lateral cutaneous nerve of the thigh and the fourth lumbar artery pass laterally across the posterior aspect of the ascending colon. Occasionally the iliohypogastric as well as the ilioinguinal nerves may also be found to cross it posteriorly. Between the posterior aspect of the ascending colon and the fascia covering the quadratus lumborum is a collection of loose, fatty areolar tissue which is continuous above with the sub-diaphragmatic areolar tissue.

Artery supply. The arteries supplying the ascending colon are the right colic branch of the superior mesenteric artery and the colic branches of the ileocolic artery (Branch of sup-mesenteric). Veins are corresponding to the arteries.

Nerve supply. It is supplied by the vagus (parasympathetics) and sympathetic nerves through coeliac and superior mesenteric ganglia.

Lymphatics. Lymphatics draining the ascending colon terminate into the superior mesenteric group of lymph nodes.

Development. It develops from the mid-gut loop (*see* development under of hind-gut).

Developmental anomalies. There may be incomplete fusion of its peritoneal attachment which may predispose the ascending colon to ptosis due to inefficient peritoneal support. Occasionally a vascular membrane or fold or vascular peritoneum may pass downwards and medially in front of the ascending colon and the caecum from the parieties on the right side. This vascular fold is known as the *Jackson's pericolic membrane*. This is due to persistence of the greater omentum which, in earlier part of development, passed in front of the ascending colon to be attached to the parietal peritoneum.

Applied anatomy. The loose, areolar fatty tissue behind the ascending colon often becomes the seat of abscess formation and by extension it may give rise to subdiaphragmatic abscess. Due to the presence of mesocolon, in some cases, intussusception may occur in this situation, particularly in children where mesocolon often presents. Ptosis of the ascending colon may occur due to incomplete fusion of its peritoneal attachment.

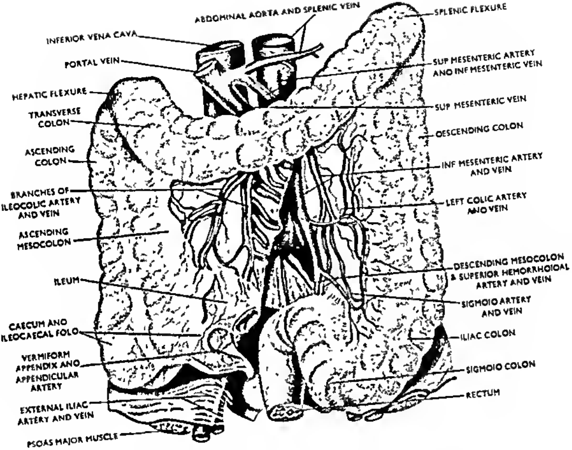
Right colic flexure. The right colic flexure is the angular junction between the ascending colon and the right end of the transverse colon. It lies in the right hypochondriac region under the ninth costal cartilage and opposite the third lumbar vertebra or a little lower than this in erect posture, and opposite the level of the second lumbar vertebra in recumbent posture.

Peritoneal relation. It is covered by peritoneum anteriorly whereas it is uncovered by peritoneum posteriorly.

General relations. *Posteriorly*, it is related to the lower lateral part of the right kidney whereas *anteriorly*, is related to the under surface of the right lobe of the liver at the colic impression. *Medially*, it is related to the fundus of the gall bladder and the second part of the duodenum. The transverse colon runs downwards forwards and to the left from the right colic flexure.

THE TRANSVERSE COLON

The transverse colon, as the name implies, is formed by that portion of the large intestine which spreads transversely across the abdominal cavity from the right to the left side. It is about 20 inches long and 2 inches broad. It begins at the right



The front view of the large intestine together with the blood vessels. With kind permission from: Lederle Laboratories Ltd. Drawn by Mr. Paul Peck.

[To face page 886]

colic flexure in the right hypochondriac region and at first descends downwards and then ascends upwards to end into the left colic flexure in the left hypochondriac region at the lateral end of the spleen. In its course across the abdominal cavity it forms an 'U'-shaped arch the convexity of which is directed downwards and forwards.

General relations. *Anteriorly*, it is covered by the superior layer of the transverse mesocolon and is related to the anterior two layers of the greater omentum which separate it from the posterior surface of the anterior abdominal wall.

Posteriorly, from the right ~~to the left side~~, it is in relation with the second portion of the duodenum, anterior surface of the head of the pancreas, upper end of the mesentery, duodenojejunal flexure and some coils of the small intestine.

Superiorly, it is related to the liver, gall bladder, greater curvature of the stomach and the lateral end of the spleen.

Inferiorly, it is in relation with some colis of the jejunum and ileum.

Artery supply. It is supplied by the ascending left colic and the middle colic arteries.

Lymphatics. Lymphatics draining the transverse colon accompany the right and the middle colic arteries and end in the right colic and the middle colic group of lymph nodes. Efferents from these nodes pass to the superior mesenteric group of lymph nodes.

The transverse mesocolon. It is a double fold of peritoneum which suspends the transverse colon from the posterior abdominal wall. Its anterior border is attached to the transverse colon while its posterior border is attached to the anterior border of the body of the pancreas. Both anteriorly and posteriorly, opposite its line of attachment, the two layers of the transverse mesocolon separate from each other and they can be traced as follows:

The transverse mesocolon as it consists of two layers of peritoneum—a superior and an inferior layer, encloses the transverse colon from in front and behind. The superior and the inferior layers of the transverse mesocolon are attached to the anterior border of the body and the anterior surface of the head of the pancreas. Traced backwards, the superior layer covers the anterior surface of the body of the pancreas and then ascends upwards as the posterior-most layer of the greater omentum, which in its course becomes adherent to but easily separable from the superior layer of the transverse mesocolon and from the anterior and the superior surfaces of the transverse colon. The inferior layer of the transverse mesocolon from its attachment to the anterior border of the pancreas runs upwards and backwards to cover the inferior surface of the body of the pancreas and then is reflected on to the third and the fourth parts of the duodenum and finally becomes continuous with the right layer of the mesentery. Around the transverse colon the two layers of the transverse mesocolon are continuous with each other. Thus it appears that both the layers of the transverse mesocolon are derived from the peritoneum of the greater sac.

Contents. The transverse mesocolon contains in between its two layers, the transverse colon, the middle colic and the ascending left colic arteries, some lymph vessels accompanying these vessels, some loose areolar tissue and a few lymph nodes and nerves.

Left colic flexure. The left colic flexure or the splenic flexure is the angle at which the transverse colon meets the descending colon in the left hypochondriac region at the lateral end of the spleen and hence it is also alternatively called the splenic flexure. It lies at a higher level than the right colic flexure and at a plane posterior to the latter. *Superiorly* it is related to the lateral end of the spleen and the tail of the pancreas. *Medially* it is related to the anterior aspect of the left kidney and *anteriorly* it comes into contact with postero-inferior surface of the stomach being

separated by the omental bursa. It is covered by peritoneum and it is connected to the diaphragm opposite the eleventh rib by a triangular fold of peritoneum known as the *phrenico-colic ligament.*

THE DESCENDING COLON

Extent and situation. It begins in the left colic flexure in the left hypochondriac region where it is continuous with the transverse colon and traversing through the left lumbar and iliac regions, it ends in the pelvic colon at the inlet of the pelvis on the medial side of the left psoas major muscle.

Length and calibre. It varies in length from 22 to 30 cm. and measures about 4 cm. in calibre. It is comparatively much narrower than the ascending colon and often found to be much contracted at places.

Course. From it commencement in the left colic flexure it at first descends downwards and medially along the lateral border of the left kidney and then descends vertically up to the iliac crest, it again curves medially and downwards, and by crossing over the left psoas major muscle, it sinks into the pelvic cavity to become the pelvic colon.

Peritoneal relation. The descending colon is covered by peritoneum both in front and at the sides and it is uncovered by peritoneum posteriorly. In some cases, the foetal condition persists and the descending colon is completely covered by peritoneum and is provided with a mesocolon, the *descending mesocolon* by which it is suspended from the posterior abdominal wall.

General relations. *Anteriorly* it is covered by the coils of the small intestine which intervene between it and the posterior aspect of the anterior abdominal wall but in the left iliac fossa it may lie in direct contact with the anterior abdominal wall, particularly when it is distended. *Posteriorly,* from above downwards, it in relation with the lower part of the diaphragm, quadratus lumborum and the iliacus and psoas being separated from them by their covering fascia. As it enters the pelvic cavity it crosses the left external iliac and testicular or ovarian vessels, and the left femoral and the genitofemoral nerves. In the iliac fossa, the lateral cutaneous nerve crosses posterior to it and in the lumbar region, the iliohypogastric and the ilioinguinal nerves cross it similarly. *Medially and above* it is related to the lateral margin of the left kidney, and below that, it is related to the left psoas major muscle. *Laterally and above* it is related to the quadratus lumborum and *laterally and below* it is in relation with the left iliacus muscle.

Artery supply. The descending colon is supplied by the left colic branch of the inferior mesenteric artery.

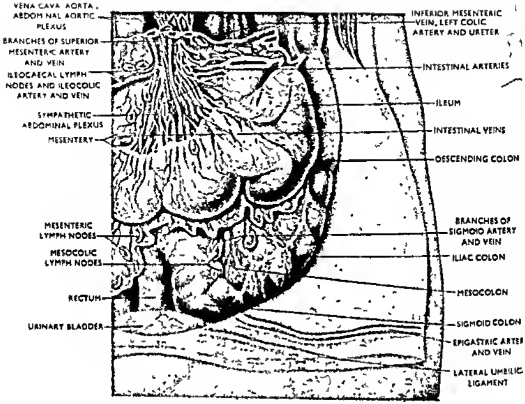
The veins are corresponding to the artery and terminate in the inferior mesen*teric vein.*

Nerve supply. The sympathetic nerves are derived from the hypogastric plexus and the lumbar sympathetic trunk whereas the parasympathetic fibres are derived from the pelvic splanchnic nerve.

Lymphatics. Lymphatics draining the descending colon terminate in the inferior mesenteric group of lymph nodes.

THE PELVIC COLON

The pelvic colon begins at the medial margin of the left psoas major muscle opposite the pelvic brim as a direct continuation of the descending colon and at first descends on the left side of the lateral wall of the true pelvis and then passes across the median plane to the right side of the pelvic cavity and finally arches backwards and downwards to reach the median plane opposite the level of the third sacral vertebra where it is continuous with the rectum.



A view of the left lower abdomen and the pelvic cavity with organs in position. With kind permission from: Lederle Laboratories Ltd. Drawn by Mr. Paul Peck. [To face page 889]

It measures about 16 or 17 inches in length but it may be as short as 5 inches r as long as 35 inches.

Peritoneal relation. The pelvic colon is completely covered by peritoneum nd is furnished with an extensive mesentery—the *pelvic mesocolon* which connects it with the posterior wall of the pelvic cavity. Due to this extensive mesocolon it is freely moveable. The pelvic mesocolon is attached in such a way that although the pelvic colon is about 16 inches long its two ends only lie at a distance of 4 inches.

General relations. In its passage to the lateral wall of the pelvic cavity it crosses the left common iliac artery and lies on the medial side of the vas deferens in case of male and the round ligament of the uterus and the ovary in case of female. *Posteriorly* it is related with the ureter, internal iliac vessels, the piriformis muscle and the sacral plexus of nerves of the left side. *Antero-inferiorly* it rests upon the bladder in case of male, and the bladder and uterus in case of female. *Antero-superiorly* it is in relation with some coils of the small intestine.

Vascular supply. It is supplied by the inferior colic branch of the left colic artery.

The *veins* are corresponding to the artery and end by opening into the inferior mesenteric vein.

Nerve supply. Same as descending colon.

Lymphatics. The lymph vessels draining the pelvic colon end into the inferior mesenteric group of preaortic lymph nodes.

Surgical importance. Due to long mesocolon with short attachment the pelvic colon is looped and the pelvic mesocolon acts as a pedicle which may be twisted on its own axis causing a condition known as *volvulus*. The two ends of the attached border of the pelvic mesocolon are separated only by 4 inches and localised peritonitis causes further approximation of the two ends, as a result of which, the pelvic colon is suspended from a short pedicle which may be easily twisted. Thus localised peritonitis predisposes to volvulus.

The pelvic colon may be highly distended causing a condition known as *megacolon*. In megacolon there is enormous distension of the colon with hypertrophy of its wall but it has least power to contract and it lies in a paralytic state.

Differences between the large and the small intestine:

Large intestine	*Small intestine*
The wall is sacculated and irregular.	The wall is smooth and uniform.
It has got taenia coli and appendices epiploicae.	It has none of them.
It has a greater calibre.	Smaller calibre.
Internally it has no aggregated lymph nodule and circular mucous folds.	It has been provided with circular mucous folds and aggregated lymph nodules.
There is no villi in the large intestine.	Presence of villi is characteristic of small intestine.
Solitary lymph nodules are numerous.	Solitary lymph nodules are less numerous.

The pelvic mesocolon. The pelvic mesocolon is a 'V'-shaped double fold of peritoneum which suspends the pelvic colon from the posterior wall of the pelvic cavity. Its anterior border splits to enclose the pelvic colon while its posterior

border or the root has a 'V'-shaped attachment on the pelvic wall. Its line of attachment begins from the medial margin of the left external iliac artery about 2 inches above its termination and then it runs upwards and medially to the bifurcation of the left common iliac artery. Then it turns sharply downwards and medially to reach the front of the third sacral vertebra where the pelvic colon ends in the rectum. Opposite to the angle of the 'V'-shaped attachment is a small peritoneal recess known as the *intersigmoid fossa*. In the floor of the intersigmoid fossa there lies the left ureter under cover of the parietal peritoneum. In between the two layers of the descending limbs of the pelvic mesocolon it contains the inferior left colic artery, superior rectal artery, lymphatics and a few lymph nodes.

THE RECTUM

The rectum forms the lower portion of the large intestine and measures about 5 inches in length. It differs from the other parts of the large intestine in that *it has no taenia, no appendices epiploicae* and its lowest portion is continuous with the anal canal with which the *skin remains attached*. It begins as a direct continuation of the pelvic colon from opposite the level of the third sacral vertebra and descends downwards in front of the sacro-coccygeal curve to the tip of the coccyx. Then it runs forwards for about 2 or 3 cm. to reach the apex of the prostate from where it bends sharply backwards to end into the anal canal. In its course it presents two antero-posterior curvatures—*a sacral curve* having a convexity backwards and a *perineal curve* having a convexity forwards. It also presents *three lateral curvatures*—one convex to the right opposite to the junction of the third and the fourth sacral vertebrae, the second, convex to the left at the sacro-coccygeal articulation and the third convex to the right opposite the tip of the coccyx. The lower part of the rectum forms a fusiform dilatation known as the *rectal ampulla*.

Peritoneal relations. Posteriorly it is uncovered by peritoneum. Anteriorly its upper-third is covered by peritoneum both in front and at the sides, the middle third is covered by peritoneum only in front while the lower-third is absolutely uncovered by peritoneum.

General relations. *Anteriorly* it is related to the rectovesical pouch containing some coils of the ileum and below that to the base of the bladder, posterior surface of the prostate, seminal vesicles and the vas deferens in case of male, and in case of female, it is related to the recto-uterine pouch, posterior fornix of the vagina and the cervix uteri. *Posteriorly*, opposite the median plane, it is related to the last three segments of the sacrum, coccyx, ano-coccygeal body and the median sacral vessels and on either side of the median plane to the piriformis and the levator ani muscles, lower sacral nerves and the lower lateral sacral artery. *Laterally* it is related to the levator ani muscles, ureter and the internal iliac vessels.

Vascular supply of the rectum. The vascular supply of the rectum consists of the arteries supplying the rectum and the veins draining it.

The *arteries* supplying the rectum are the superior rectal branch of the inferior mesenteric, middle rectal branch of the internal iliac and the inferior rectal branch of the internal pudendal artery.

The superior rectal artery is the main artery supply of the rectum and it begins as a direct continuation of the inferior mesenteric artery and descends downwards between the two layers of the pelvic mesocolon and reaching the level of the third sacral vertebra it divides into two branches which descend one on each side of the rectum. Reaching the middle of the rectum, each artery breaks up into smaller branches which pierce the wall of the gut and descend downwards between the muscular and mucous layers as far as the level of the sphincter-ani-internus where they anastomose each other and form loops around the lower part of the rectum; and these arterial loops communicate with the middle rectal branch of the internal iliac and the inferior rectal-branch of the internal pudendal artery. The *superior rectal artery supplies the whole of the mucous membrane and the upper part of the musculature of the*

rectum. The lower part of the musculature of the rectum is supplied by the middle and inferior rectal arteries.

The *venous drainage* of the rectum is arranged in the form of a plexus, the *rectal plexus* which lies around the lower part of the rectum and the anal canal. The rectal plexus consists of an inner plexus lying in between the muscular and the mucous coats and an outer plexus lying outside the muscular wall. These two plexuses communicate each other by small veins which pierce the muscular wall.

The lower part of this plexus is drained by the inferior rectal vein opening into the internal pudendal veins which is a systemic vein. The middle part of the plexus is drained by the middle rectal vein opening into the internal iliac vein (Systemic vein.)

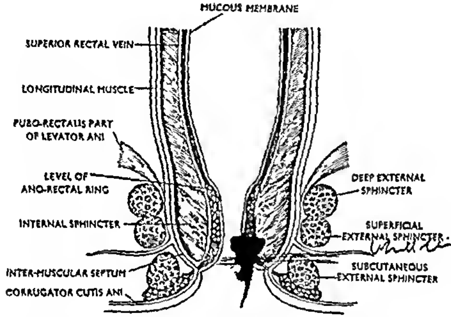


Fig. 723. A coronal section of the rectum and anal canal.

The upper part of the plexus is drained by five or six veins which ascend upwards between the muscular and mucous coats and reaching the middle of the rectum, they all unite to form a single vein which pierces the muscular wall and ascends upwards as the *superior rectal* vein which opens into the inferior mesenteric vein (which is a vein of the portal system). Thus through the rectal venous plexus there exists a communication between the portal system of veins and the systemic veins.

Lymphatics of the rectum. The lymphatics of the rectum consist of two sets of lymph vessels—(1) *Intra-mural and extra-mural.*

(1) The intra-mural set of lymph vessels lie within the wall of the rectum and they (intra-mural set of lymph vessels) communicate with a lymph sinus which lies between the wall of the rectum and the surrounding fat.

(2) The extra-mural set of lymph vessels lie outside the wall of the rectum and it is drained by three sets of lymph vessels upper, middle and lower.

(a) The *upper set* of lymph vessels accompany the superior rectal vessels and traversing through the para-rectal group of lymph nodes, end into the *left common iliac group of lymph nodes.*

(b) The *middle set* passes along the middle rectal artery and ends in the *internal iliac group of lymph nodes.*

(c) The *lower set* of lymph vessels pass into two directions. Some vessels, that is, those draining the anal canal and the lower part of the rectum pierce the levator ani muscle, accompany the inferior rectal artery, traverse the ischiorectal fossa and then passing along the internal pudendal vessels end into the *internal iliac lymph nodes.*

The remaining lymph vessels of the lower set, that is, those draining the rest of the rectum pass on the upper surface of the levator ani muscle between it and the pelvic fascia and end in the *internal iliac lymph nodes.*

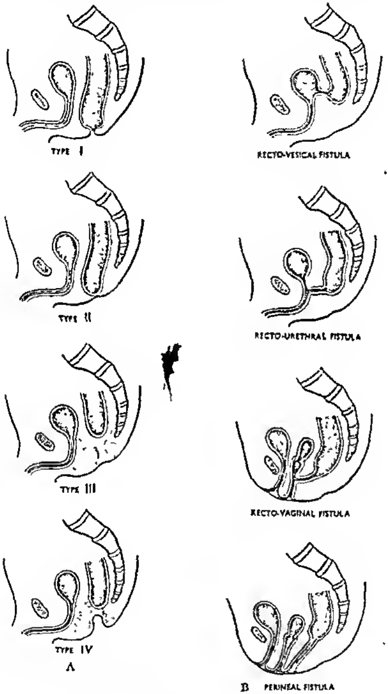


Fig. 724. The different types of ano-rectal anomalies.

The efferent lymph vessels from all these lymph nodes, either directly or indirectly, end in the pre-aortic lymph nodes around the origin of the inferior mesenteric artery.

Development. The hind gut ends below into a blind pouch known as the *cloaca* which is connected to the body stalk by a canal known as the *allantoic* canal. At a later stage the ventral portion of the cloaca becomes wider and the dorsal portion becomes narrower. In the wider ventral portion the mesonephric (Wolffian) and the paramesonephric (Mullerian) ducts open and in between these two portions (ventral and dorsal portions) the mesodermal tissue grow rapidly and push the wall of the cloaca downwards and inwards. As a result, a septum appears in between the two portions of the cloaca and from the anterior portion the *urinary bladder* develops and from the posterior part the *rectum* develops. The uro-rectal septum ultimately reaches the cloacal membrane *i.e.*, the bottom of the cloaca where the entodermal cloaca lies in direct contact with the ectoderm and the two portions are completely separated from each other, but for some time, a communication exists between the ventral and the dorsal portions of the cloaca before the uro-rectal septum is complete and this canal is known as the *cloacal duct*. At the bottom of the cloacal membrane there is a depression, the *proctodeum*, which is subsequently deepened and the rectum is communicated to the exterior. Thus it is evident that the upper part of the anal canal and the rectum develop from the entoderm whereas the lower part of the anal canal develops from ectoderm and the line of junction between the two developmental distinct areas is demarcated by the presence of the pectinate line situated at the lower end of the anal columns.

Developmental anomalies. The anomalies arise due to irregularities of the fusion processes and due to failure of the cloacal membrane to rapture. Due to former different types of ano-rectal fistulae such as recto-vesical, recto-urethral recto-vaginal and perineal may develop (see fig. no. 724B). Due to the latter imperforate anus such as type I, II, III and IV. In type I the anus is of pin-hole type. In other three types the internal communication is absent and the gut lies at a variable depth from the surface (see fig. no. 724A).

Structure of the rectum. The rectum consists of (a) serous and fascial coats, (b) muscular coat, (c) submucous coat and (d) the mucous coat.

(a) *Serous and fascial coat.* The serous coat is formed by the peritoneum which incompletely invests the upper two-thirds of the rectum. The fascial coat is derived from the pelvic fascia and covers the lower one-third of the rectum.

(b) *Muscular coat.* The muscular coat consists of outer longitudinal and inner circular muscle fibres. The longitudinal muscle fibres of the rectum differ from the other parts of the large intestine in that they form two distinct bundles, one being present anteriorly and the other posteriorly. The circular muscle fibres surround the inner aspect of the longitudinal bands and opposite the lower part of the anal canal they are thickened to form *the internal sphincter*.

(c) *Submucous coat.* In the submucous coat there lie the vessels and nerves supplying the rectum.

(d) *Mucous coat.* Opposite the lateral flexures of the rectum the mucous membrane of the rectum are infolded to form shelf-like inward projections which extend half-way round the gut and is known as the Houston's valves or *semilunar valves*. There are three semilunar valves, two on the right side and one on the left side corresponding to the lateral flexures of the rectum. They support the column of faeces.

The anal canal. The lowest one and a half inches of the gastro-intestinal tract constitutes the anal canal. It begins from the lower end of the rectum opposite the apex of the prostate and ends in the anus. It lies below the peritoneal level and consequently is devoid of any peritoneal covering. It is surrounded by sphincter ani internus, levator ani (pubo-rectalis) and the sphincter ani externus. It lies in front of the ano-coccygeal body and behind the perineal body. At the junction between the rectum and the anal canal an important muscular ring, known as the *ano-rectal ring*, surrounds this part of the gut and is formed posteriorly and at the sides by the union of the longitudinal fibres of the rectum with the sphincter ani externus. Anteriorly this ring is weaker because the pubo-rectalis is absent in this situation.

Interior of the anal canal. The upper part of the interior of the anal canal is lined with mucous membrane whereas its lower part is lined with modified skin and this muco-cutaneous junction is marked by a wavy line known as the *pectinate line.* The upper part of the anal canal presents a series of longitudinal mucous folds (6-10 in number) known as the *anal columns*. Each anal column is formed by the infoldings of the mucous membrane and some of the longitudinal muscle fibres of the anal canal and contains within it a straight vein and a small artery respectively. These anal columns are separated from one another by a furrow, the lower ends of which are joined to one another by a cresentic fold of mucous membrane known as the *anal valve.* In between two anal columns, under cover of the anal valve, is a pocket-like recess known as the *anal sinus.* The muco-cutaneous junction or the pectinate line marks the position of the proctodeal membrane of the embryo and remains of this membrane may be indicated by the presence of a few short epithelial processes at the lower end of the free margins of the anal valve known as the *anal papillae.* About 3 to 9 mm below the pectinate line, the inner lining of the anal canal is marked by a white line known as the *Hilton's line.* (This is not a true white line but a colour contrast between the colour of the skin and that of the mucous membrane. The area between the pectinate line and the Hilton's white line is known as the '*pecten*' (resembling a comb) and is lined by transitional epithelium.

Supports of the rectum. The Following are the supports of the rectum.

(1) Perineal and the ano-coccygeal bodies.
(2) Levator ani muscle.
(3) Recto-urethralis muscle.
(4) Recto-vesical septum:
   (*a*) Anterior fascia of Denonvilliers.
   (*b*) Posterior fascia of Denonvilliers.
   (*c*) Space of Denonvilliers.
(5) Pelvic fascia.
(6) Rectal Stalk of Elliot Smith (Lateral ligament of rectum).
(7) The fibro-fatty tissue in the ischiorectal fossa on either side.
(8) Fascia of Waldeyer and membranous stalk which encloses the superior rectal vessels, extends from the hollow of the sacrum to the ampulla of the rectum.

(1) Perineal and ano-coccgeus bodies. The perineal body in front and the ano-coccygeal body behind form two fixed points which suspend it by fibres spreading from these points.

(2) Levator ani muscle. The 'pubo-rectalis' portion of the levator ani forms a sling around the anal canal and suspends the same from above. The pubo-coccygeus proper fixes the anal canal between two bony points (pubis and coccyx) and thus forming an effective support

(3) Recto-urethralis muscle. It consists of a band of muscle fibres which extends from the rectal ampulla to the apex of the prostate and are continuous with the muscle fibres surrounding the uretura at that situation.

(4) Recto-vesical septum. It extends from the peritoneum above to the uro-genital diaphragm and the perineal body below. It is the obliterated portion of the peritoneal recess in the foetus formed between the rectum and the bladder and the prostate and consist of anterior and posterior layers and a potential space between the two layers. The anterior layer is known as the *anterior fascia of Denonvilliers* while the posterior, the *posterior fascia of Denonvilliers.*

(5) Pelvic fascia. The visceral layer of pelvic fascia by spreading between the different pelvic viscera also add to the support of the rectum.

(6) Rectal stalk of Elliot Smith. It consists of two dense processes of fibrous tissue, one on each side, that extends from the 2nd, 3rd and 4th anterior sacral foramina to the back of the rectum and lies at a distance of about 2·5 cm. from the margin of levator ani. The band contains the middle rectal vessels and the pelvic splanchnic nerves.

(7) Fibro-fatty tissue of the ischiorectal fossa. Acting as a packing material on each side of the rectum they also add to the security of the rectal supports.

Structure of the anal canal. Its wall is composed of *muscular*, *subepithelial* and *epithelial coats.*

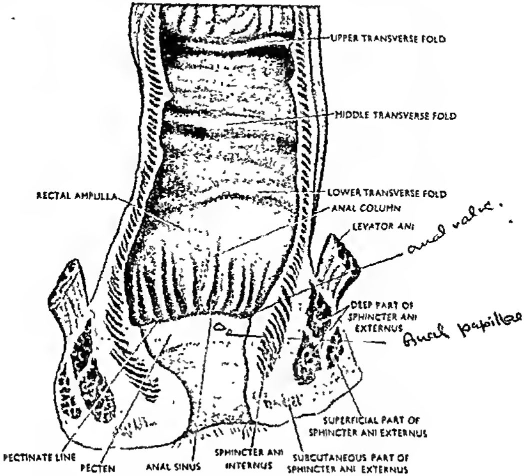


Fig. 725. The interior of the rectum and the anal canal.

The muscular coat of the anal canal consists of *outer longitudinal* and *inner circular fibres.* Superiorly the *longitudinal fibres* of the anal canal are continuous with the similar fibres of the rectum. Inferiorly they invest the sphincter ani internus and reaching the lower end of the latter they end by blending with a fibro-muscular septum known as the *anal intermuscular septum.* This septum intervenes between the lower border of the sphincter ani internus and the superficial portion of the sphincter ani externus. Below the muco-cutaneous junction this septum is firmly adherent to the inner lining of the anal canal and is marked by a depression externally known as the *anal intermuscular sulcus.* At the ano-rectal junction the longitudinal fibres blend with the sphincter ani externus, levator ani and the sphincter ani internus to form the *ano-rectal ring.* Two small bundles of longitudinal fibres extend posteriorly to be attached to the coccyx and are known as *recto-coccygeal muscles.* Similar bundles extend anteriorly to be attached to the membranous portion of the urethra and the prostate in case of male and to the vagina in case of female and are known as the *recto-urethralis muscles.*

The *circular muscles fibres* of the anal canal are continuous above with the circular muscle fibres of the rectum. Opposite the ano-rectal junction they are specially thickened to form the sphincter ani internus.

The *sphincter ani internus* lies at a distance of about half an inch from the anus.

The sub-epithelial coat contains some loose areolar tissue in which the vessels and nerves are embedded.

The epithelial coat forms the muco-cutaneous lining of interior of the anal canal and has already been described.

Importance of the pectinate line:

(1) It marks the line of junction between the two development distinct areas and the here the squamous stratified epithelium of the skin meets the columnar epithelium of the gut.

(2) The external sphincter ends and the internal sphincter begins opposite this level. Levator ani passes between these two sphincters.

(3) Both the anal and the deep fascia of the ischio-rectal fossa end opposite this line.

(4) The cerebrospinal nerve which supplies the skin meets the sympathetic nerve which supplies the gut in this line.

(5) The anal valve lies opposite this line.

(6) The superior rectal vein (Portal system of vein) communicates with the middle and inferior rectal veins (systemic veins) at this line.

(7) The portion below this line is drained by lymphatics which end into the superficial group of inguinal lymph nodes while the portion above it is drained by vessels which end into the internal iliac group of lymph nodes.

Sphincters of the alimentary tract. The whole alimentary canal beginning from the mouth to the anus measures about 29 feet in length and the passage of foods from mouth to anus is guided by certain mechanisms in which the passage is regulated and the sphincters are the prime factors in it. Each sphincter is placed between two different sections of the alimentary tracts and acts as a stopping station like that of the railway transport system. Above each sphincter the passage of food is temporarily stopped by the sphincter concerned so as to regularise it for the subsequent passage. The following are the situations where they are placed.

(1) *Lower pharyngeal sphincter.* Between the junction of the pharynx and oesophagus.

(2) *Cardiac sphincter.* Between the oesophagus and the cardiac end of the stomach.

(3) *Pyloric sphincter.* Between the stomach and the duodenum.

(4) *Iliocolic sphincter.* Between the large and small intestines.

(5) *Mid-colic sphincter.* Between the proximal 1/3 and distal 2/3 of the transverse colon.

(6) *Recto-colic sphincter.* Between the lower end of the pelvic colon and the rectum.

(7) *Internal and external anal sphincters.* Surround the lower part of the anal canal.

Thus we see that the whole alimentary tract is subdivided into different sections by the interposition of the sphincters and these are popularly known as *oesophageal section, gastric section, iliocolic section, mid-colic section* and *the rectocolic section.* Just like the heart muscle the musculature of each of these sections has an inherent quality of rhythmical contraction and the initial contraction primarily starts in the proximal part of the section and is gradually propagated to the rest of it. As in cases of heart muscle, the contraction wave starts in the most excitable point, so here too, the first wave of contraction starts in the proximal end of each section which constitutes its most excitable point and the excitability becomes less and less as it descends to the distal part of the section. Hence the wave passes normally towards the anus except at the mid-colic section where antiperistaltic waves can and do arise. In pathological conditions antiperistalsis may however take place.

There is intimate harmony between the work of one section with the other and any irregularity in any section has its repercussion in the other and once the work has started in one section the other section also begins to set at work so as to regularise the passage of its content, as for example, when gastric section passes into section

on taking some food or drink a simultaneous action starts in the distal ileum (gastrocolic reflex) and the ilial contents are passed to the caecum.

Almost all the sphincters are formed by localised thickening of the circular muscle fibres of the gut except the external sphincter of the anus which is a distinct muscle and has a bony origin. The ilio-colic sphincter, in addition, has a valvular arrangement.

Sphincter ani externus. It is a fusiform voluntary muscle that surrounds the last two centimeters of the anal canal, and the anus. It consists of three portions, *subcutaneous*, *superficial* and the *deep*. The *subcutaneous* portion has no bony attachment and consists of a few fibre bundles which encircle the anus and decussate both in front of and behind the anus and are fused with the skin. The superficial portion forms the main mass of the sphincter and arises posteriorly from the tip of the cocyx by a narrow tendon which gives rise to fibres which are arranged into two flattened sheets, one on each side of the anal canal. Anteriorly the two sheets meet together and are inserted into the perineal body. Some of the fibres of the superficial portion becomes continuous with the fibres of the transversus perinei superficialis, bulbospongiosus, levator ani. The deep portion is also devoid of any bony attachment and forms a thick ring around the lower 2/3 of the anal canal and is attached anteriorly to the perineal body. Some of its fibres are also blended with the transverse superficial perineal muscles.

Relations. It is surrounded by the fat of the ischiorectal fossa externally whereas it surrounds the sphincter ani internus internally. Its deepest fibres are in contact of the mucous membrane of the anal canal.

Actions. Having no antagonistic members the sphincter ani externus remains in a state tonic contraction and thus keeps the anus closed. On voluntary effort it tightens its grip around the anus firmly.

Nerve supply. It is supplied by three nerves (S. 3,4), its anterior part is supplied by muscular branch of the perineal nerve, the intermediate part by the inferior haemorroidal branch of the pudendal nerve and its posterior portion by the perineal branch of the 4th sacral nerve.

THE RESPIRATORY SYSTEM

The respiratory system consists of a group of organs which are designed to convey air and to provide a mechanism in which blood and air come into intimate relation with each other, so that, gaseous exchange occurs between the two, the oxygen of the air is absorbed by the blood and the carbon dioxide is eleminated into the air. Thus the respiratory system consists of organs of respiration, that is, the lungs, in which gaseous exchange takes places, and a series of air passages connecting the exterior to the lungs. The air passages consist of the nasal cavities, pharynx, larynx and the trachea and its ramifications. The pharynx has already been dealt with in the digestive system and in this system the rest of the air passages together with the lungs have been described. For convenient studies the external nose and the paranasal sinuses have also been included in this system.

Evolution of the Respiratory System. The series of events that give rise to the development of the human respiratory system, such as, the formation of the pharyngeal diverticulum and the lung buds, the pleural cavities, the diaphragm, which completely separates the pleural cavities from the abdominal cavity, and the formation of the inspiratory and expiratory groups of muscles, and the vascular mechanism associated with the respiratory system are not only complicated but they are, at some stages, unintelligible. If we trace the evolutionary path of the respiratory system from the lower to the higher forms, many a complicated part of the human development becomes understandable without much difficulty. Thus, in the following few lines, the events that follow from the lower to the higher forms, have been described briefly.

In the fishes the respiratory mechanism is comparatively simpler and the respiratory function is mediated through four pairs of gills. Thus the work of the lungs in man is conducted by the gills in the fishes who have no separate respiratory passages and pleural apartment with lungs. However, they have other accessory respiratory appendages, such as, the swim bladder and well-developed branchial and pharyngeal musculature and a nervous system controlling their activities.

The swim bladder is an evagination from the pharynx which contains oxygen. The branchial and pharyngeal muscles are mechanically adapted to force water through the branchial clefts which helps the process of gaseous exchange in the branchiae.

In most of the amphibians the swim bladder is bifid and is confined within the abdominal cavity. The swim bladder does the work of the lung and is connected to the pharynx by a respiratory passage. The vascular system for each lung (each half of the bifid swim bladder) is derived from the sixth visceral arch. The pharyngeal muscles are concerned in pumping air into the lung and thus they act as muscles of inspiration. The muscles of the body wall are modified to form the muscles of expiration.

In the reptiles the respiratory system is more elaborate than that of the amphibians. The air passages consist of nasal passages, mouth cavity, glottidis, larynx, trachea, bronchi, bronchioles and air spaces within the lungs. There are two flank muscles, one on each side, which enlarge the coelom by their contraction and the air is sucked into the lungs, and thus, these flank muscles represent the functions of the mammalian diaphragm and form the inspiratory muscles. The expiration is carried out by a expiratory muscle consisting of four bellies, two anterior and two posterior, each belly lying on each side of the median plane; the bellies are connected together by a tendon which passes across the mid-ventral line. By their contraction the four bellies compress the viscera against the lungs and thus the air is forced out of them.

In the birds the air passages are almost similar to those of the reptiles except that they have localised dilatation, the *vocal organ* or *syrinx*, at the bifurcation of the trachea. The presence of syrinx is a peculiar feature to the birds. Moreover, the bronchioles are connected with numerous large, thin-walled air sacs which extend variously between the organs, in the spaces in the neck, and into the cavities of larger bones.

In the mammals, further specialisation occurs in the formation of two pleural cavities which are completely separated from the abdomen by the formation of the diaphragm which is a mammalian characteristic. The bronchioles divide and subdivide into finer ramification and ultimately end by opening into alveolar sacs which enormously increase the respiratory areas.

THE EXTERNAL NOSE

The nose is the median, three-sided pyramid on the face situated above the oral aperture and between the two eyes. It forms the peripheral organ of smell and provides air passages which connect the exterior to the pharynx. It consists of external nose and two nasal cavities separated from each other by a median septum, the *nasal septum*.

The external nose consists of a root, an apex, a dorsum, two side-walls and an ıferior wall containing the two nostrils separated from each other by the median :ptum. The side-walls of the nose meet anteriorly to form the dorsum. Superiorly ıe dorsum meet the forehead at the root whereas inferiorly it ends into a free end nown as the apex or the tip of the nose. The nostrils are two elliptical openings on ıe inferior aspect of the nasal pyramid. Each nostril is bounded by the median :ptum medially and by the lower part of the side-wall known as the ala of the nose ıterally.

Functionally the external nose can be divisible into an upper fixed part and a ›wer moveable part. With quiet respiration the movement of the ala of the nose not visible but in respiratory difficulty the movement of the ala of the nose becomes isible and in such condition the elliptical nostril becomes more rounded by the ulging out of the ala of the nose.

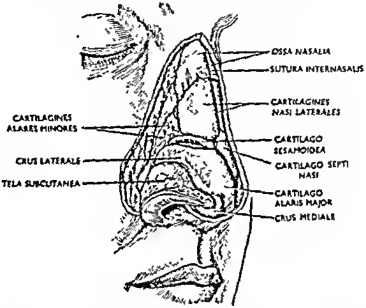


Fig. 726. Skeletal structures of the external nose. With kind permission from Callander: Surgical Anatomy, W. B. Saunders' Company, Philadelphia and London.

Structurally the nose consists of an osseo-fibrocartilaginous framework which is ined externally by the skin and internally by the mucoperiosteum. The bony ıart corresponds to the fixed portion of the nose and is formed by the nasal bones nd by the frontal processes of the two maxillae. The lower moveable part of the ıose is mostly cartilaginous and partly fibrous. The fibrous part lies below the artilaginous part and lies at its lower end adjoining the margin of the nostril; opposite he ala of the nose there is no subcutaneous tissue and the skin remains fixed to the ınderlying cartilage.

The cartilaginous part of the nose consists of larger upper and lower cartilages ınd a few smaller cartilages. The *upper cartilage* is triangular in form and lies below he lower end of the nasal bone. Its base is directed backwards and is attached to he maxilla and the nasal bone by fibrous tissue. Its apex is directed forwards, lownwards and medially and comes into contact with the septal cartilage. Its ınterior margin is directly continuous with the septal cartilage. Its lower edge is :onnected witb the lower cartilage by some fibrous tissue. The *lower cartilage* bounds the nostril laterally and in front, and is bent on itself towards the dorsum of the nose so as to form a short curved plate known as the septal process whicb comes in the formation of the septum of the nose. Posteriorly the lower cartilage is attached to the maxilla by some fibrous tissue and in the latter, two or three small cartilages are embedded.

Vascular supply. The arteries supplying the external nose are the branches from the facial artery and the dorsal nasal branch of the ophthalmic artery.

The **veins** drain into the facial vein mostly and a few drain into the ophthalmic vein.

Lymph vessels. The lymph vessels draining the root of the nose pass laterally along the upper and the lower eye lids and drain into the superficial parotid lymph nodes whereas the rest of the nose is drained by vessels which follow the facial vein and terminate into the submandibular lymph nodes.

Nerve supply. The muscles of the nose are supplied by the branches from the facial nerve (motor narve). The sensory nerves for the external nose are the infra-trochlear and the external nasal branches of the nasocilliary nerve which is a branch from the ophthalmic division of the trigeminal nerve.

THE NASAL CAVITIES

The nasal cavities are two bilateral cavities, right and left, which are situated above the roof of the mouth on either side of the median plane and are separated from each other by a median septum—the *nasal septum*. Each cavity has an anterior aperture, a posterior aperture (choana), a floor, a roof, a medial and a lateral wall.

The *anterior aperture* or the *nostril* is an oval opening on each side of the median plane above the upper lip and it is directed downwards and communicates the nasal cavity with the exterior.

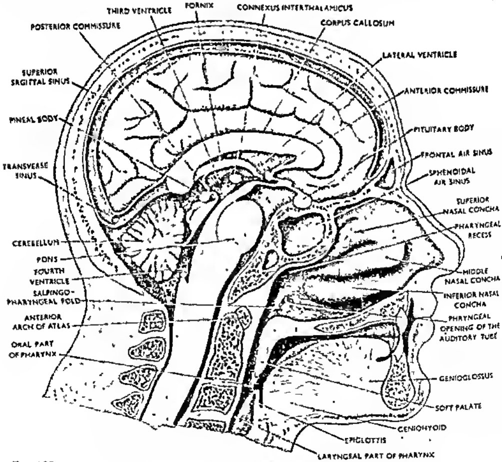


Fig. 727. A sagittal section of the head and neck showing the lateral wall of the nasal cavity.

The *posterior nasal aperture* (choana) is much larger than the anterior aperture and is oblong in shape and is directed backwards. It communicates the nasal cavity with nasopharynx and through the latter with the mouth cavity, the tympanic cavity, rest of the pharynx and with the larynx. It is bounded medially by the posterior border of the vomer which corresponds to the posterior border of the nasal septum; laterally by the perpendicular plate of the palatine bone; above by the undersurface of the body of the sphenoid and below by the posterior part of the hard palate.

The *floor* is formed by the superior surface of the hard palate. It is concave from side to side and measures about half an inch in width and three inches in length between the roof and the floor.

The *roof* consists of an anterior part, an intermediate and a posterior part; the anterior part corresponds its position with the bridge of the nose and is formed by the union of the two lateral cartilages of the nose, the two nasal bones and the nasal spine of the frontal bone; the intermediate part is formed by the undersurface of the cribriform plate of the ethmoid bone and the posterior part is formed by the undersurface of the body of the sphenoid bone.

The *medial wall* or the *septum of the nose* is the median partition between the two nasal cavities and is formed mainly by the perpendicular plate of the ethmoid bone, the vomer and the septal cartilage of the nose and partly by the crest formed by the two maxillae, crest formed by the two palatine bones, the crest formed by the two nasal bones and the nasal spine of the frontal bone. The nasal septum is traversed by the long sphenopalatine vessels and nerves, the medial branches of the olfactory nerve and by the branches of the anterior ethmoidal vessels and nerves.

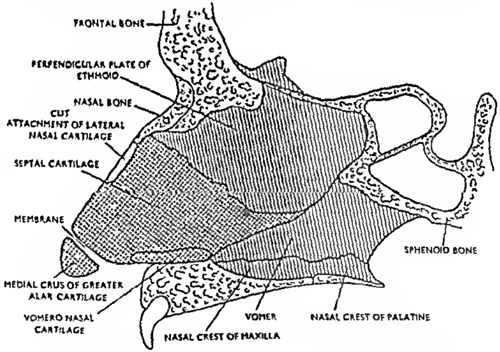


Fig. 728. The composition of the nasal septum. With kind permission from Prof. Hollinshead Ph.D., *Anatomy for the Surgeons*, Vol. 1, Paul B. Hoeber Inc.

The *lateral wall* of the nasal cavity presents three elevations formed by the superior, middle and the inferior nasal conchae from above downwards. Each nasal concha is a curved plate of bone, the convex surface of which forms an elevation on the lateral wall of the nasal cavity and the hollow of the curve forms a space known as the *meatus* and according to their situations they are known as the superior, middle and the inferior meatuses of the nose.

The *superior meatus* intervenes between the superior nasal concha and the posterior part of the middle nasal concha. Above the posterior part of the superior nasal concha there is a shallow triangular depression known as the *spheno-ethmoidal recess*. The sphenoidal air sinus opens into the spheno-ethmoidal recess. The posterior ethmoidal air sinus also opens into the superior meatus of the nose.

The *middle meatus* of the nose intervenes between the middle nasal concha and the inferior nasal concha. It does not occupy the whole length of the lateral wall of the nasal cavity and the portion lying in front of the middle meatus forms a shallow depression known as the *atrium of the nose*. The bulk of the middle meatus is hidden by the middle nasal concha and when the middle nasal concha is removed it is found to present a rounded elevation the *bulla ethmoidalis* (caused by the middle ethmoidal air cell) and curving forwards and upwards is a curved passage beneath the bulla ethmoidalis known as the *hiatus semilunaris*. Into the hiatus semilunaris of the middle meatus, the maxillary, middle and anterior ethmoidal and the frontal air sinuses open in order from behind forwards. The frontal air sinus opens through a narrow passage known as the *fronto-nasal duct*.

The *inferior meatus* of the nose lies under cover of the inferior nasal concha and intervenes between it and the floor of the nasal cavity. Anterior to the inferior meatus and the inferior nasal concha there is a shallow depression (inner side of the lateral cartilage of the nose) known as the *vestibule*. The atrium lies above it. Into the inferior meatus the naso-lacrimal duct opens. The vestibule is covered by skin and on it there are some coarse hairs.

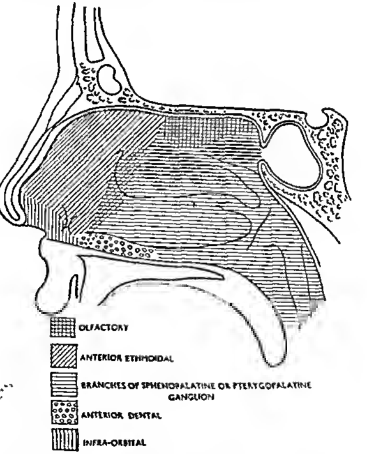


Fig. 729. The general distribution of nerves to the lateral nasal wall. With kind permission from Prof. Hollinshead Ph.D., Anatomy for the Surgeons, Vol. I, Paul B. Hoeber Inc.

To sum up, the frontal, anterior ethmoidal, middle ethmoidal and the maxillary air sinuses open into the middle meatus of the nose; the sphenoidal and the posterior ethmoidal air sinuses open into the spheno-ethmoidal recess and the superior meatus of the nose respectively. Into the inferior meatus the naso-lacrimal duct opens.

Nerve supply of the nasal cavity. The nerve supply of the nasal cavity consists of (A) nerves of special sensibility (sensation of smell) and (B) nerves of general sensibility.

(A) *Nerve of special sensibility.* The olfactory nerve is the nerve of special sensibility and carries smell sensations from the olfactory region of the nose, that is, the arch of the superior nasal concha, the adjoining portion of the nasal septum and the superior meatus of the nose.

(B) *Nerve of general sensibility:*

(1) *Nasal septum*: (*a*) The upper and posterior part of the nasal septum is supplied by the short sphenopalatine nerves, (*b*) the middle part by the long sphenopalatine nerve, and (*c*) the anterior part by the anterior ethmoidal nerve (through internal nasal branch).

(2) *Lateral wall*: (*a*) The inferior meatus and the inferior nasal concha are supplied by the anterior superior dental nerves and by the greater palatine nerves, (*b*) the middle meatus and the middle nasal concha are supplied by the anterior superior dental nerves and by the greater palatine nerves, (*c*) the superior meatus and the superior nasal concha by the short sphenopalatine nerves, (*d*) the atrium by the internal nasal branch of the anterior ethmoidal nerve, and (*e*) the vestibule by the external nasal branch of the anterior ethmoidal nerve.

Blood supply of the nasal cavity:

(1) *Anterior* and *posterior ethmoidal arteries*—supply the upper and anterior part of the nasal cavity.
(2) *Long and short sphenopalatine arteries*—supply the posterior part of the nasal cavity.
(3) *Superior labial branch of the facial artery*—supply the antero-inferior part of the nasal septum.

The *veins of the nasal cavity* form highly distensible cavernous tissue and add warmth and moisture to the inspiratory air. They mainly end into the pterygoid venous plexus.

PARANASAL SINUSES

The paranasal sinuses are bilaterally paired air chambers which communicate with the nasal cavity and are developed by a process of evagination of the nasal mucous membrane which extends into the bones surrounding the nasal cavities. They are frontal, ethmoidal, sphenoidal and maxillary. Although bilaterally paired they are usually asymmetrical. Each is lined with mucoperiosteum which extends from the nasal cavity and is covered by ciliated epithelium. The mucoperiosteum is less glandular, less vascular and thinner than that of the nasal cavity.

Functions of paranasal sinuses. (1) Paranasal sinuses are air chambers which occupy deploic spaces and contain air and consequently it is a Nature's economy which makes the bone lighter.

(2) By virture of their containing air and communication to the nasal cavity they act as resonant chambers and help in phonation of speech.

(3) The air they contain, is kept at body temperature, and during inspiration, by the interaction this air of body temperature with the outside air, an equilibrium of temperature of the inhaled air is maintained.

Frontal sinuses. They are two in number, right and left, and each is situated behind the medial end of the corresponding superciliary arch. They are separated from each other by a median septum which may be deflected to one or the other side

and consequently they are usually asymmetrical. They are roughly triangular in shape and occupy the deploie spaces of the frontal bone and each can be roughly outlined by three points—one in the nasion, one about one inch above it and another at the junction of lateral 2/3 with the medial 1/3 of the supraorbital margin.

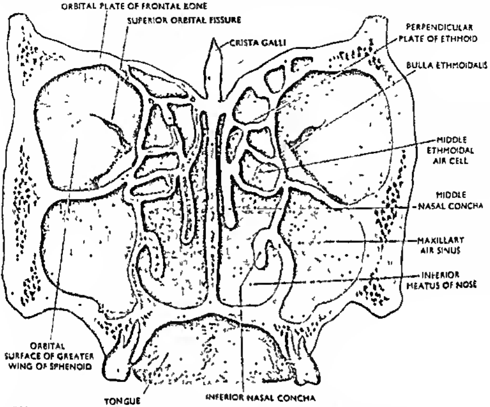


Fig. 730. A coronal section of the skull showing the cavities of the nose and the paranasal sinuses.

Topographically it is frontal but developmentally it is ethmoidal because it is formed by extensions of the ethmoidal air cells which invade the vertical plate of the frontal bone.

Each frontal air sinus opens into the infundibulum of the middle meatus of the nose through fronto-nasal duct. Its secretion tends to flow along the hiatus semilunaris and usually passes into the maxillary air sinus through its opening which is situated close to roof of the maxillary air sinus. An adult frontal air sinus has the following measurements:

Width—1 inch.
Height—1¼ inches.
Antero-posterior diamenter—1/2 inch.

Development. At birth the frontal air sinuses are shallow depressions opposite the root of the nose. At about eight month, extensions from the ethmoidal air cells invade the vertical plate of the frontal bone and extend up to the nasion; during the third year of life they are of considerable size, and between 7th and 8th years, they are a little short of their adult form and they are fully developed just before puberty.

Vascular supply. The frontal air sinuses are supplied by branches from supra-orbital vessels.

Nerve supply. The frontal air sinuses are supplied by the branches from the supraorbital nerves.

Ethmoidal air sinuses. The ethmoidal air cells or sinuses are numerous thin-walled cavities situated within the labyrinth of the ethmoid and are completed by the frontal, maxillary, sphenoidal, lacrimal and palatine bones. They, on each side, are placed between the two vertical plates of the labyrinth of the ethmoid and are arranged into three groups, anterior, middle and posterior. The anterior ethmoidal air sinuses open into the infundibulum of the middle meatus of the nose, the middle ethmoidal air cells into the middle meatus on or above the bulla ethmoidalis while the posterior ethmoidal air cells open into the superior meatus of the nose.

Development. The ethmoidal air cells begin to develop during intraembryonic life. Anteriorly they extend into the frontal bone to form the frontal air sinus.

Artery supply. They are supplied by anterior and posterior ethmoidal arteries.

Nerve supply. The anterior and middle ethmoidal air sinuses are supplied by the anterior ethmoidal nerves while the posterior ethmoidal air cells are supplied by the posterior ethmoidal and pharyngeal nerves.

Sphenoidal sinuses. The sphenoidal air sinuses are two in number separated from each other by a median septum which is usually deflected to one or the other side and consequently they are asymmetrical. The sphenoidal air sinus opens into the spheno-ethmoidal recess of the superior meatus of the nose. They occupy the body of the sphenoid and many extend into the basilar part of the occipital bone. The average dimension of the sinus is as follows:

Width	.. $\frac{7}{8}$ inch.
Height	.. 1 inch.
Anterior-posterior	.. 1 inch.

Development. It develops by evagination of the nasal mucous membrane and at birth they form small cavities. At about 6th year they are about 3/4 inch in diameter and they gradually increase in size till puberty when they are fully developed.

Artery supply. They are supplied by posterior ethmoidal arteries.

Nerve supply. The sphenoidal air sinuses are supplied by branches from the posterior ethmoidal nerves and the pharyngeal nerve.

Maxillary air sinus (the antrum of Highmore). The maxillary air sinus is the largest of all and is a four-sided hollow pyramid. It occupies the body of the maxilla and consists of a base, an apex, a roof, a floor, an anterior wall and a posterior wall. Its *medial* or *nasal surface is its base* and is directed towards the nasal cavity. *Its apex corresponds to the zygomatic process of the maxilla.* The *roof* is formed by the orbital surface. The *floor* is formed by the alveolar process. The *anterior wall* is formed by the anterior surface while the *posterior wall* is formed by the posterior surface of the body of the maxilla.

Its walls are translucent. The infraorbital canal forms a ridge on its roof and anterior wall. The floor is lower than the floor of the nasal cavity and on it the roots of the molar teeth form two or three ridge-like elevations which correspond to the roots of the molar teeth. The first molar tooth usually produces maximum bulging of the floor of the sinus. Except the incisors, which develop along with the premaxilla, the roots of any of the other teeth may project into it. The anterior superior dental vessel and nerves occupy similar gutters on the anterior or facial wall. Each maxillay air sinus has the following average dimensions:

Width	.. 1 inch.
Height	.. $1\frac{1}{2}$ inches.
Antero-posterior	.. $1\frac{1}{4}$ inches.

The maxillary air sinus opens into the hiatus semilunaris of the middle meatus of the nose close to the roof of the sinus and the opening is slit-like.

Artery supply. The arteries supplying the maxillary air sinus are the posterior superior dental branch of the maxillary, anterior superior branch of the infraorbital and by the middle dental artery.

Nerve supply. The nerves supplying the sinus are the posterior superior, anterior superior and middle dental, and the pharyngeal nerves from the sphenopalatine ganglion.

Development. It is formed by evagination of the nasal mucous membrane and forms a shallow groove on the medial wall of the nasal cavity by the fourth month of intrauterine life. It attains its normal size after complete eruption of the permanent teeth.

THE LARYNX

The larynx, the organ of voice, forms the upper part of the respiratory passages and extends from the root of the tongue to the lower border of the cricoid cartilage opposite the level of the sixth cervical vertebra from where it becomes continuous with the trachea. Superiorly it opens into the laryngeal part of the pharynx and inferiorly it is continuous with the trachea.

Relations. *Anteriorly* it is covered by the skin, the superficial and the deep fascia, and *posteriorly*, it is related to the laryngeal part of the pharynx which separates it from the fourth, fifth and the sixth cervical vertebrae. On either side it is related to the sternohyoid, superior belly of the omohyoid, sternothyroid and the thyrohyoid muscles, the upper pole of the thyroid gland and the carotid sheath containing the common carotid artery, internal jugular vein and the vagus nerve.

Measurements. The different measurements of the larynx vary in the two sexes and they are tabulated as below:

	In males	*In females*
Length	44 mm.	36 mm.
Breadth or transverse diameter ..	43 mm.	41 mm.
Antero-posterior diameter	36 mm.	26 mm.

Structure of the larynx. The structural framework of the larynx consists of nine laryngeal cartilages, three paired and three single, which are connected to one another by ligaments and membranes. It is lined internally by mucous membrane and gives attachment to muscles, both internally underneath the mucous membrane and externally, which are concerned in its different movements.

Cartilages of the larynx. The cartilages of the larynx are as follows:

Single cartilages:	Paired cartilages:
(1) Epiglottis.	(1) Two arytenoid.
(2) Thyroid.	(2) Two cuneiform.
(3) Cricoid.	(3) Two corniculate.

Epiglottis. It is a leaf-like thin plate of *yellow elastic cartilage* which intervenes between the base of the tongue and the inlet of the larynx. It consists of upper, lower and two lateral borders and two surfaces, anterior or lingual and posterior or laryngeal.

The *upper border* is free and convex and is continuous with the lateral borders on each side. Its *inferior border* forms its stem which is attached to the angle formed by the two laminae of the thyroid cartilage a little below the thyroid notch by the thyro-epiglottic ligament. The upper part of each *lateral border* is free while its lower part is contained within the ary-epiglottic fold of mucous membrane.

The upper part of the *anterior surface* is free while its lower part is connected to the dorsum of the tongue opposite the median plane by a fold of mucous membrane known as the *glosso-epiglottic fold* and on either side it is connected to the side-walls of the pharynx by the *pharygo-epiglottic folds*. A deep depression between the dorsum

of the tongue and the lower part of its anterior surface on either side of the median plane is known as the *vallecula.* The lower part of the anterior surface is placed behind the hyoid bone and thyrohyoid membrane and it is connected with the former by an elastic ligament known as the *hyo-epiglottic ligament.* The *posterior* or the *laryngeal surface* of the epiglottis is concave from side to side but concavo-convex from the above downwards. A low rounded elevation at its lower part is called the *tubercle.*

Thyroid cartillge. This is the largest of all the cartilages of the larynx and forms a median prominence in front of the neck. It consists of two laminae which are fused anteriorly to form an angle, the angle of the thyroid cartilage, which is open posteriorly and makes a subcutaneous prominence anteriorly known as the *laryngeal prominence* (Adam's Apple). The laryngeal prominence is less marked in the females but it forms a well-marked visible prominence in the adult males.

Superiorly the two laminae are separated from each other by a V-shaped notch known as the *thyroid notch.*

Each thyroid lamina is irregularly quadrilateral in form and consists of four borders, anterior, posterior, superior and inferior and two surfaces, outer and inner.

The *anterior border* is fused with the fellow of its opposite side at an angle which measures about 90° in the males and about 120° in the females. It is convex anteriorly and concave posteriorly. The *posterior border* is thick and rounded and is prolonged both upwards and downwards and forms the superior and inferior horns respectively. The *superior horn* gives attachment to the lateral thyrohyoid ligament whereas the inferior horn is curved medially and presents a facet which articulates with the cricoid cartilage. The *superior* or *upper border* is convex in front and concave behind and gives attachment to the thyrohyoid membrane. Posteriorly a little in front of the superior horn it presents a small tubercle known as the *superior thyroid tubercle.* The *inferior border* is concave posteriorly and straight anteriorly and at the junction between the two parts is a small tubercle, the *inferior thyroid tubercle.* The inferior border gives attachment to the cricothyroid ligament and the cricothyroid muscle.

The *outer surface* is concavo-convex and is marked by an *oblique line* which extends from the superior to the inferior thyroid tubercles. The oblique line gives insertion to sternothyroid and origin to thyrohyoid and the inferior constrictor muscle of the pharynx. The *inner surface* gives attachment to the vestibular and vocal ligaments and to the thyroarytaenoideus, thyroepiglotticus and the vocalis muscles on either side. The angle formed by the two laminae gives attachment to the thyro-epiglottic ligament.

Cricoid cartilage. The cricoid cartilage is situated below the thyroid cartilage and its lower border forms the lowest limit of the larynx. It resembles a signet-ring in appearance and consists of a quadrilateral plate which lies posteriorly and an anterior arch.

The *quadrilateral plate* or the lamina of the cricoid cartilage is broad and thick and measures from 2-3 cm. in vertical length. It consists of two surfaces, anterior and posterior and four borders, superior, inferior and two lateral. Its anterior or internal surface is lined with mucous membrane. Its posterior or external surface presents a median, vertical ridge which gives attachment to the two fasciculi of the longitudinal fibres of the oesophagus in its upper part. On either side of the ridge is a depressed area which gives origin to the cricoarytaenoideus posterior.

The *anterior arch* of the cricoid is narrow in front and wider behind as it approaches the lamina. Its narrow anterior portion measures about 1/4 inch in vertical diameter. From either side, anteriorly, it gives origin to cricothyroideus, and posteriorly, it gives origin to the inferior constrictor muscle of the pharynx. On each side at the junction of the lamina with the arch is a circular facet for articulation with the inferior horn of the thyroid.

The lower border of the cricoid is horizontal and is connected with the highest ring of the trachea by the *cricotracheal ligament.* The upper border is directed obli-

quely upwards and backwards. Its anterior part gives attachment to the *crico-vocal membrane* and the cricoarytaenoideus lateralis; posteriorly it presents a median notch and an oval convex area on either side which articulates with the base of the arytaenoid cartilage.

Arytaenoid cartilages. The arytaenoid cartilages are placed on the upper border of the lamina of the cricoid on the posterior part of the larynx. Each is pyramidal in shape and consists of three surfaces, a base and an apex.

The *base* is concave and articulates with the upper border of the lamina of the cricoid. Its postero-lateral end forms a *muscular process* which gives insertion to cricoarytaenoideus posterior behind and the cricoarytaenoideus lateralis in front. From its anterior part a short process projects horizontally forwards and is known as the *vocal process* which gives attachment to the vocal ligament. Its *apex* curves backwards and medially and articulates with the corniculate cartilage. Its surfaces are posterior, anterolateral and medial. The *posterior surface* is concave and is covered by the arytaenoideus transversus. The *antero-lateral surface* is convex and is marked by an irregular ridge. In the lower part, this ridge intervenes between two depressed areas, upper and lower. To the upper area the *vestibular ligament* is attached while the lower one gives attachment to the *vocal ligament* and to the crico-arytaenoideus lateralis. The *medial surface* is flat and smooth and is covered by mucous membrane.

Corniculate cartilages. The corniculate cartilages are two small conical nodules of *yellow elastic cartilage* and each is contained within the aryepiglottic fold being placed at the apex of the arytaenoid carti age.

Cuneiform cartilages. They also form two small nodules of *yellow elastic cartilage* and are contained within the aryepiglottic fold supero-lateral to the corniculate cartilage.

Joints of the larynx. The a ticulation between the inferior horn of the thyroid and the cricoid is a synovial joint and each is enveloped by a capsular ligament which is lined internally by synovial membrane. Rotatory movements are permitted in this joint. The articulations between the base of the arytaenoids and the cricoid cartilage are also synovial joints. Gliding and rotatory movements are permitted in these joints.

Ligaments of the larynx. The ligaments of the larynx may be subdivided into extrinsic and intrinsic ligaments. The extrinsic ligaments are those which connect the upper and lower parts of the larynx with the adjacent structures while the intrinsic ligaments connect the different cartilages of the larynx to one another.

EXTRINSIC LIGAMENTS. The extrinsic ligaments are the thyrohyoid membrane, lateral and median thyrohyoid ligaments and the crico-tracheal ligament.

Thyrohyoid membrane. It is a broad fibro-elastic membrane which connects the thyroid cartilage with the hyoid bone. Inferiorly it is attached to the upper border of the thyroid cartilage in front of the superior horns and superiorly it is attached to the upper border of the posterior surface of the body and the greater cornu of the hyoid bone and is separated from the body of the hyoid by a bursa. Opposite the median plane it is thickened to form the *median thyrohyoid ligament.* On either sides it is comparativly thin and is pierced by the internal laryngeal nerve and the superior laryngeal vessles of which the latter lies below the former. Externally it is partially covered by the infrahyoid muscles and internally it is lined by mucous membrane.

Lateral thyrohyoid ligament. It forms the posterior border of the thyrohyoid membrane and is cord-like. It connects the tips of the superior horns of the thyroid with the tips of the greater horns of the hyoid bone. Within the folds of this ligament sometimes there is a small nodule of cartilage known as the *cartilage triticea.*

Hyoepiglottic ligament. It connects the hyoid bone with the epiglottis.

Crico-tracheal ligament. It connects the lower border of the cricoid cartilage with the first ring of the trachea and is continuous below with the fibrous membrane that invests the rings of the trachea together.

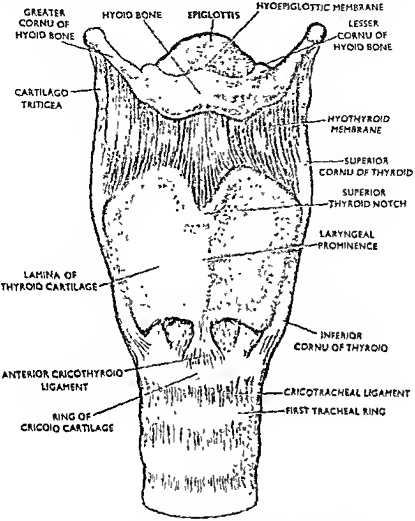


Fig. 731. A front view of the larynx and a part of the trachea.

INTRINSIC LIGAMENTS. Underneath the mucous membrane of the larynx is a broad fibro-elastic membrane, the *elastic membrane* of the *larynx* which connects the different laryngeal cartilages together. On either side it is subdivided into upper and lower parts by the interval between the vestibular and vocal ligaments. Its upper part extends between the arytaenoid cartilages and the epiglottis and is ill-defined. Its lower part is well-defined and is known as the *crico-vocal membrane* which connects the cricoid, thyroid and arytaenoid cartilages together.

Crico-vocal membrane. The crico-vocal membrane consists of an anterior and two lateral parts. The anterior part or the crico-thyroid part connects the cricoid and the thyroid cartilages. Externally on either side it is overlapped by the crico-thyroid muscles and opposite the median plane it is subcutaneous. It is transversely crossed by the arterial arch formed by the anastomosis of the crico-thyroid branches of the superior thyroid arteries. Twigs from this arch pierce the ligament. Internally it is lined by the mucous membrane of the larynx. The lateral part of the crico-vocal membrane is thinner and extends upwards and medially from the inner edge of the superior border of the cricoid cartilage. Anteriorly it is attached to the deep surface of the thyroid angle and posteriorly to the inferior surface and to the tip of

the vocal process of the arytaenoid cartilage. In between the anterior and posterior attachments the intervening crico-vocal membrane is thickened to form the *vocal ligament.*

Vestibular ligament. They are two in number and each is contained within the vestibular fold of mucous membrane. Each is attached anteriorly to the deep part of the angle of the thyroid cartilage immediately below the thyroepiglottic ligament and posteriorly it is attached to the antero-lateral surface of the arytaenoid cartilage a little above the vocal process.

Vocal ligaments. They are also two in number and each is contained within the vocal fold. It is formed by the upper border of the crico-vocal membrane and is attached anteriorly to the thyroid angle and posteriorly to the vocal process of the arytaenoid cartilage.

Cavum laryngis. The cavity of the larynx extends from the laryngeal inlet, by means of which it communicates with pharynx, to the lower border of the cricoid cartilage where it is continuous with the trachea. It is incompletely divided into three compartments by two pairs of mucous folds situated one above the other and projects transversely into the cavity of the larynx. The upper pair of mucous folds is known as the *vestibular folds* whereas the lower pair is known as the *vocal folds.* The portion of the larynx extending from the laryngeal inlet to the vestibular folds is known as the *vestibule* or the *upper subdivision of the larynx;* the portion between the vestibular and vocal folds is known as the *middle subdivision of the larynx* and the portion below the vocal folds constitutes the *lower subdivision of the larynx.*

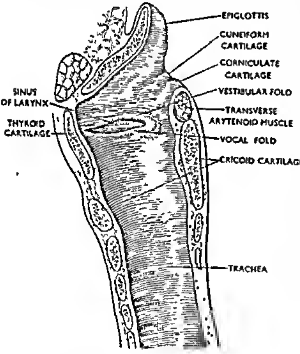


Fig. 732. The cavum laryngis.

The vestibule of the larynx. This is the upper subdivision of the larynx and intervenes between the laryngeal inlet or the upper opening of the larynx and the vestibular folds. Its upper part is wider than its lower part. It is bounded in front by the epiglottis and the thyroepiglottic ligaments, both of which are covered by mucous membrane. Posteriorly it is bounded by that portion which lies in between the arytaenoid cartilages. On either side it is bounded by the ary-epiglottic fold. On the ary-epiglottic fold there are two small rounded elevations situated one in front of the other and are formed by the cuneiform cartilage in front and the cornicula'e cartilage behind. The vestibule communicates below with the middle subdivision of the larynx and above with the pharynx through the laryngeal inlet.

Middle subdivision of the larynx. The middle subdivision of the larynx lies in between the vestibular folds above and the vocal folds below. The fissure in between the two vestibular folds is known as the *rima vestibuli* and that between the vocal folds is known as the *rima glottidis.* The pocket-like recess on the lateral wall of the larynx between the vestibular and the vocal folds is known as the *sinus of the larynx.* A blind diverticulum from the upper part of the sinus extends upwards between the vestibular fold and the inner surface of the thyroid cartilage and is known as the

saccule of the larynx. This saccule of the larynx contains numerous glands which pour out their secretions into the sinus of the larynx and always keeps the vocal folds lubricated. The middle subdivision of the larynx communicates below with the lower subdivision.

Rima glottidis. It is the fissure between the vocal folds and the arytaenoid cartilages. The portion intervening between the two vocal folds constitutes the intra-membranous part of the rima glottidis while the portion between the two arytaenoid cartilages with its vocal processes constitutes its intra-cartilaginous part. In the male it measures about one inch in length, and in the females, three-fourth inch. The rima glottidis is the narrowest part of the larynx and the fissure changes its shape and form during phonation and respiration. When the two vocal folds are approximated (adducted) high-pitched sounds are produced whereas when they are dilated (abducted) low-pitched sounds are produced.

Lower subdivision of the larynx. The lower subdivision of the larynx lies below the vocal folds and extends up to the lower border of the cricoid cartilage. It is elliptical in shape at its upper part and is more or less rounded below. It communicates below with the trachea.

Mucous membrane of the larynx. The mucous membrane of the larynx is continuous above with the mucous membrane of the pharynx and mouth and below with the mucous membrane of the trachea. Over the lingual or anterior surface of the epiglottis and along the aryepiglottic folds and below the vocal folds it is loosely attached and there is an underlying areolar layer. Over the laryngeal or posterior surfaces of epiglottis and the cuneiform and arytaenoid cartilages it is firmly attached to the underlying cartilages and there is absence of the submucous layer. Along the vocal folds it is very thin and is firmly adherent to the underlying tissue and there is no submucuous layer.

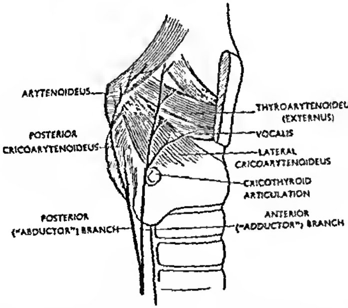


Fig. 733. Schema of the distribution of the recurrent laryngeal nerve. With kind permission from Prof. Hollinshead Ph.D., Anatomy for the Surgeons, Vol. I, Paul B. Hoeber Inc.

Along the aryepiglottic and the vocal folds it is covered by stratified squamous epithelium but over the rest of its extent it is ciliated columnar. Taste-buds like bodies are found over the aryepiglottic folds, laryngeal surface of the epiglottis, medial surface of the arytaenoids and over the vestibular folds. Except over the vocal folds mucous glands are numerous and they are abundantly present over the saccule of the larynx.

N.B. Oedema of the glottis cannot spread into the vocal folds because of the mucous membrane being firmly adherent to the underlying tissue and the absence of the submucous layer in this situation. The oedema usually affects those portions where the mucous membrane is loosely attached to the underlying cartilage through the medium of a sub-mucous layer, that is, over the lingual surface of the epiglottis, the aryepiglottic folds and over the lower subdivision of the larynx.

Muscles of the larynx. The muscles of the larynx may be subdivided into extrinsic and intrinsic group of muscles.

The extrinsic group of muscles consist of suprahyoid and infrahyoid muscles and have already been described. The following are the intrinsic muscles of the larynx.

(1) Cricothyroideus, pars oblique and pars recta.
(2) Cricoarytaenoideus lateralis.
(3) Cricoarytaenoideus posterior.
(4) Arytaenoideus transversus.
(5) Arytaenoideus obliquus.
(6) Aryepiglotticus.
(7) Thyreoarytaenoideus.
(8) Vocalis.
(9) Thyreoepiglotticus.

Cricothyroid. It is triangular in form and arises from the anterolateral aspect of the cricoid cartilage. Its fibres are grouped into straight and oblique parts. The straight fibres are inserted into the lower border of the thyroid cartilage while the oblique fibres are inserted into the anterior border of the inferior horn of the thyroid cartilage.

Cricoarytaenoideus lateralis. It is a small muscle which arises from the upper border of the arch of the cricoid and ascending upwards and backwards it is inserted into the arytaenoid cartilage in front of its muscular process.

Cricoarytaenoideus posterior. It arises from the depression on either side of the ridge on the back of the lamina of the cricoid and ascending upwards and laterally it is inserted into back of the muscular process of the arytaenoid.

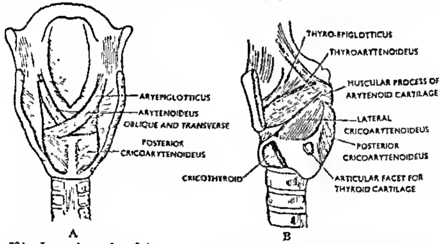


Fig. 734. Internal muscles of the larynx. A. From behind after removal of the pharynx and oesophagus. B. From the side after partial removal of the thyroid cartilage. With kind permission from Prof. Hollinshead Ph.D., Anatomy for the Surgeons, Vol. I, Paul B. Hoeber Inc.

Arytaenoideus transversus. This is the only unpaired muscle of the larynx and bridges the gap between the two arytaenoid cartilages posteriorly. It extends between the muscular processes of the two arytaenoid cartilages.

Arytaenoideus obliquus. It lies superficial to the preceding muscle and consists of two fasciculi which cross each other like the letter. "X". Each fasciculus extends from the back of the muscular process of one arytaenoid cartilage to the apex of the cartilage of the opposite side. Some of the fibres from the apex ascend into the aryepiglottic fold and form the *aryepiglotticus* muscle.

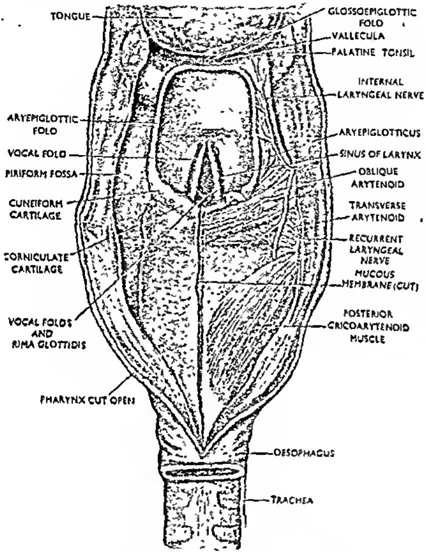


Fig. 735. The larynx exposed from behind. Note the position of the recurrent laryngeal and internal laryngeal nerves.

Thyroarytaenoideus. It consists of lateral and medial portions. The *lateral portion* arises from the lower half of the inner surface of the thyroid lamina, from the outer aspect of the crico-vocal membrane and passing upwards, backwards and laterally it is inserted into the antero-lateral surface of the arytaenoid; some of its fibres are prolonged into the epiglottis to form the *thyro-epiglotticus.*

The *medial portion* is deeply situated and arises from the lower part of the thyroid cartilage and is attached to the lateral aspect of the vocal process of the arytaenoid. This band is called the *Vocalis.*

Actions of the laryngeal muscles. The *extrinsic muscles* of the larynx are mainly concerned with the upward and downward movements of the larynx as a whole. The suprahyoid muscles are concerned in elevating the larynx and the trachea while the infrahyoid muscles are concerned in depressing the same.

The *intrinsic muscles* of the larynx act in such a way that they regulate the condition of the rima glottidis by which they effect in producing sound and modify its pitch. In executing this action they either make the vocal folds tense or relax or they either adduct or abduct the same. Their actions are summarised as follows:

Adductors of the vocal folds:
(1) Cricoarytaenoidei lateralis.
(2) Arytaenoideus transversus.
(3) Arytaenoideus obliquus.

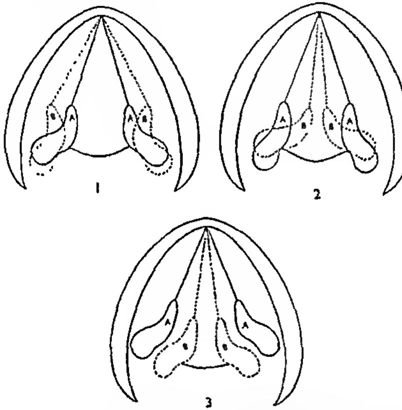


Fig. 736. The different forms of the rima glottidis by the action of the laryngeal muscles.
(1) Abduction of the rima glottidis A—B.
(2) Adduction of the rima glottidis A—B
(3) Partial closure of glottidis. Both vocal folds and arytaenoid cartilages are in adduction.

Abductors of the vocal folds:
Cricoarytaenoidei posteriores.

Tensors of the vocal folds:
Cricothyroidei muscles.

Relaxation of the vocal folds:
By thyroaretaenoidei and vocalis muscles.

Vascular supply of the larynx. The arteries supplying the larynx are the superior and inferior laryngeal arteries. The superior laryngeal artery is a branch of the superior thyroid artery and enters the larynx by piercing the thyrohyoid membrane below the internal laryngeal nerve. It anastomoses with the inferior laryngeal artery within the larynx. The inferior laryngeal artery arises from the inferior thyroid artery and accompanying the recurrent laryngeal nerve it enters the larynx where it anastomoses with the superior laryngeal artery.

The *superior* and the *inferior laryngeal veins* open into the superior and inferior thyroid veins respectively.

Lymphatics of the larynx. The lymphatics of the larynx consists of superior and inferior groups of lymph vessels. The superior group of lymph vessels drain the larynx above the rima glottidis and they pierce the hyothyroid membrane and end in the upper deep cervical lymph nodes. The inferior group of lymph vessels drain the larynx below the rima glottidis and piercing the cricothyroid membrane they end mainly in the lower deep cervical lymph nodes and partly into the prelaryngeal lymph nodes.

The prelaryngeal lymph nodes. They lie on the median portion of the cricothyroid membrane in between the two cricothyroid muscles and they form a group of one or two small lymphatic nodules. In addition to the lymphatics draining the larynx below the rima glottidis they receive lymph vessels from the upper part of the trachea and from the upper part of the isthmus of the thyroid gland. Their efferents either pass into the lower deep cervical lymph nodes or to the pretracheal group of lymph nodes.

Nerve supply of the larynx. The nerves supplying the larynx consist of motor and sensory nerves and the sympathetic filaments from the superior cervical ganglion which accompany the superior laryngeal nerve.

Motor nerves. The recurrent laryngeal nerves are the true motor nerves of the larynx and they supply all the muscles of the larynx except the cricothyroideus which is supplied by a branch of the external laryngeal branch of the superior laryngeal nerve. The arytaenoideus has got double nerve supply and it is supplied by a branch from the internal laryngeal branch of the superior laryngeal nerve in addition to the recurrent laryngeal nerve.

Sensory nerves. The internal laryngeal nerves are the true sensory nerves of the larynx and they supply both the surfaces of the epiglottis, the aryepiglottic folds and the mucous membrane of the larynx as far as the vocal folds. Below the vocal folds the mucous membrane of the larynx is supplied by the recurrent laryngeal nerves, which are sensory in this part.

N.B.—It is evident from the nerve supply of the larynx that the recurrent laryngeal, though a true motor nerve, supplies some sensory filaments to the larynx and the internal laryngeal nerve, though a true sensory nerve, provides some motor filaments to the larynx. The reason for this peculiar nature of the nerve supply is that within the larynx the two nerves, that is, the recurrent laryngeal nerve and the internal laryngeal nerve break up into a plexiform network and interchange their fibres with each other, and as a result, the recurrent laryngeal receives some filament from the internal laryngeal nerve and the internal laryngeal receives some motor filament from the recurrent laryngeal nerve.

Development of the larynx. The larynx forms the upper part of the respiratory system which develops from the median ventral diverticulum of the foregut which at first arise as a groove known as the *tracheobronchial groove.* The distal portion of the foregut below the diverticulum rapidly lengthens to form a narrowed lumen (oesophagus). Later on, two longitudinal grooves, one on each side, appear with corresponding ridges internally. With further growth the grooves deepen and the ridges approach each other and gradually fuse together from below upwards except superiorly where a communication exists between the respiratory system and the foregut. It is due to developmental anomallies that the fusion is incomplete and the larynx or the trachea may communicate with the oesophagus by abnormal openings.

The *lining epithelium* and the mucous glands develop from the diverticulum whereas the *muscles of the larynx* develop from the mesoderm of the ventral aspect of the foregut. The *epiglottis* develops from the hypobranchial eminence and the *arytaenoid cartilages* from the arytaenoid swelling on the ventral aspect of the pharynx. The *other cartilages* of the larynx develop from the branchial mesoderm surrounding the upper part of the respiratory diverticulum.

Piriform fossa or recessus piriformis. The piriform fossa is a small recess situated on each side of the laryngeal orifice. It is bounded medially by the aryepiglottic fold; laterally by the inner surface of the lamina of the thyroid cartilage and the thyrohyoid membrane. Covered by mucous membrane, and lying under cover of the same, in this situation, is the internal laryngeal nerve.

The presence of the piriform fossa facilitates the movements of the epiglottis and the larynx; it is a catch point for foreign bodies.

THE TRACHEA AND THE BRONCHI

The *trachea* or the *windpipe* is a fibro-musculo-cartilaginous tube which carries air to— and from the lungs. It is roughly cylindrical with a flattened, membranous posterior wall and forms a tube which maintains its patency all the time.

Commencement, Course and termination. It begins in the neck as a direct continuation of the larynx at the lower border of the cricoid cartilage opposite the level of the sixth cervical vertebra and coursing vertically downwards through the lower part of the front of the neck it enters into the thorax through the thoracic inlet. In the thorax it runs downwards through the superior mediastinum and finally ends by dividing into right and left bronchi opposite the level of the lower border of the fourth thoracic vertebra. In its course downwards it is usually placed in the middle line except opposite its point of bifurcation where it lies a little to the right of the median plane. As it traverses through both the neck and the thorax, for descriptive purposes, it is divided into a cervical part and a thoracic part.

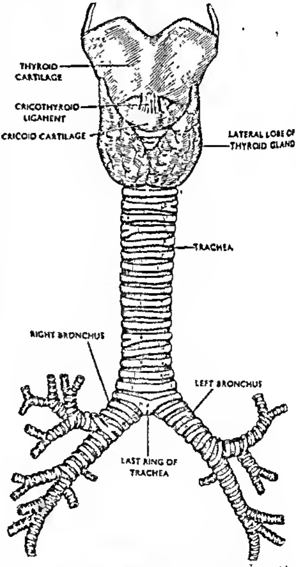


Fig. 737. The front view of the larynx with thyroid gland and the trachea with the bronchi.

Measurements in the adult:

Length	..	4-5 inches
Breadth	..	1/2 an inch approximately.

In the females it is slightly smaller in length as well in its diameter. In the children it is proportionately smaller.

Relations. *Cervical part.* The cervical part of the trachea forms its most superficial part and can be felt easily without any difficulty.

Anteriorly it is covered by skin, superficial fascia, platysma and deep fascia and is overlapped by the sternohyoid and sternothyroid muscles. The isthmus of the thyroid gland crosses it transversely deep to the preceding muscles opposite

the second, third and fourth tracheal rings. Above the isthmus is the anastomosing loop formed by the anastomosing branches of the two superior thyroid arteries. Below the isthmus it is in relation to the inferior thyroid vein and the remains of the thymus gland. *Posteriorly* it is related to the oesophagus which separates it from the vertebral column and the longus cervicis muscle. The recurrent laryngeal nerves, one on each side, ascend in the groove between the trachea and oesophagus. On either side the trachea is related to the common carotid and inferior thyroid arteries and the lobes of the thyroid gland.

Thoracic part. The thoracic part of the trachea passes downwards through the superior mediastinum and is related, above and in front, to the manubrium sterni, origins of sternohyoid and sternothyroid muscles. Below and in front it is related to the arch of the aorta, left common carotid and brachiocephalic or innominate arteries, and the left, brachiocephalic (innominate) vein. It is also related to the deep part of the cardiac plexus of nerves and some lymph nodes.

Posteriorly the trachea is related to the oesophagus which separates it from the vertebral column and the longus cervicis muscles.

On the right side are the brachiocephalic or innominate artery, the arch of the azygos vein, the right lung and pleura and the right vagus nerve.

On the left side it is related to the left common carotid and the left subclavian arteries, the left side of the arch of the aorta and the left recurrent laryngeal nerve.

N.B.—In the children the innominate artery crosses in front of the cervical part of the trachea opposite the upper border of the manubrium sterni. The arteria thyroid ima, when present lie, in front of it in the cervical region. The innominate and left common carotid arteries at first lie in front of the thoracic part of the trachea, and later on, owing to their divergence from each other, the innominate comes to the right and the left common carotid to the left. The left recurrent laryngeal nerve at first lies between the arch of the aorta and the left side of the trachea and then ascends in the groove between the trachea and the oesophagus.

Artery supply. The trachea is supplied by branches from the inferior thyroid artery.

The *veins* open into the thyroid venous plexus.

Lymphatics. The lymph vessels draining the trachea end in the pretracheal and paratracheal group of lymph nodes.

Nerve supply. The nerves supplying the trachea are derived from the vagus, sympathetic and the recurrent laryngeal nerves.

Development. The trachea is a foregut derivative and begins as a tracheal groove which appears immediately behind the hypobronchial eminence. The tracheal groove is soon converted into a diverticulum which invades the splanchnic mesoderm intervening between the pericardium in front and the foregut behind. This diverticulum is the primitive trachea and at about 5 mm. stage it becomes bifid at its caudal part and forms the primodia of the primary bronchi. Each of the primary bronchi later on forms the lung bud from which lung develops.

The Bronchi. The trachea terminates by dividing into right and left bronchi opposite the lower border of the fourth thoracic vertebra. Each bronchus after a short course enters into the lung at its hilus and divides and sub-divides into finer ramifications within the lung and ultimately each of these finer ramifications ends by communicating with a group of, thin-walled air spaces, the *lung alveoli*, through a common chamber. Thus each of the bronchi takes a short *extra-pulmonary course* and a longer *intra-pulmonary ramifications.*

The right bronchus. *Extra-pulmonary course and relations.* The right bronchus begins at the bifurcation of the trachea opposite the level of the lower border of the fourth thoracic vertebra and ends by dividing into eparterial and hyparterial bronchi at the hilus of the lung opposite the level of the fifth thoracic vertebra where they take on to their intra-pulmonary course. It measures about one inch in length and

is wider, shorter and more vertical than the left and consists of six to eight incomplete cartilaginous rings like the trachea. It is directed downwards and to the right and in its course it passes behind the ascending aorta and the right pulmonary artery. The arch of the azygos vein is related posterior to it.

The EPARTERIAL or the LOBAR BRONCHUS lies above the level of the pulmonary artery and forms the lobar, or secondary bronchus for the upper lobe of the right lung. It measures about 1/4 inch in length and arises from the lateral aspect of the right bronchus and soon enters into the substance of the lung.

The HYPARTERIAL BRONCHUS lies below the pulmonary artery and forms the lobar or secondary bronchus for the middle and the lower lobes. About 3/4 inch from its origin it gives out a branch to the middle lobe of the right lung and then descends downwards, backwards and laterally for about 3/4 inch to enter into the substance of the lower lobe. Below the origin of the bronchus to the middle lobe the hyparterial bronchus gives out an apical bronchus which is distributed to the upper part of the lower lobe.

Intra-pulmonary ramifications. The eparterial or the secondary bronchus divides into three tertiary or lobular bronchi, apical, posterior (sub-apical) and anterior or pectoral. The *apical bronchus* passes upwards and backwards to the apex of the lung. The posterior (sub-apical) bronchus is directed backwards and upwards and divides into lateral and posterior branches each of which again divides into upper and lower branches which are distributed to the posterior part of the upper lobe. The *anterior* or *pectoral bronchus* runs downwards and forwards to be distributed to the rest of the upper lobe. Soon after its origin it gives out lateral and anterior branches which are distributed as above.

The middle-lobe-bronchus divides into two tertiary or lobular bronchi, medial and lateral. The lower-lobe-bronchus divides into five tertiary or lobular bronchi, apical, anterior basal, posterior basal, lateral (axillary) basal and medial basal (cardiac).

The left bronchus. *Extra-pulmonary course and relations.* It measures about 2 inches in length and is longer, narrower, more oblique than the right and consists 9-12 incomplete rings. It begins at the bifurcation of the trachea opposite the level of the lower border of the fourth thoracic vertebra and ends at the hilus of the lung opposite the level of the sixth thoracic vertebra. It runs downwards and to the left from below the arch of the aorta and crosses in front of the oesophagus, thoracic duct and the descending thoracic aorta. The left pulmonary artery at first lies above it and then in front of it. It does not provide any eparterial bronchus.

At the hilus of the lung the left bronchus divides into two branches—upper and lower. The upper branch is distributed to the upper lobe while the lower is distributed to the lower lobe.

Intra-pulmonary ramifications. The **upper lobe bronchus** divides into upper and lower branches. The *upper branch* after a short course of about 1 cm. gives out an *anterior branch* and then ascends further upwards to terminate by dividing into *apical* and *posterior branches.* Their further subdivisions are identical with those on the right side. The lower division of the upper lobe bronchus is known alternatively as the *lingular bronchus* which is distributed to the lower and the anterior part of upper lobe. It gives out a small lateral branch and then divides into superior and inferior lingular branches.

The **lower lobe bronchus** on the left side is distributed exactly in the same way as on the right side except that it has no medial basal branch (cardiac).

Thus it appears that the primary or the main bronchus divides into secondary or lobar bronchi and each lobar or secondary bronchus sub-divides into tertiary bronchi or the bronchi of zonal distribution. *Each tertiary bronchus with its ramifications and the lung alveoli in connection with them form the individual respiratory district or lobule which is an independent functional unit of the lung having its own blood vessels, nerves, lymphatics and connective tissue investment and is known as the bronchopulmonary segment.*

Each bronchopulmonary segment is surrounded by connective tissue investment which is continuous with the connective tissue of the visceral pleura together with the blood vessels, nerves and lymphatics and forms the independent respiratory district for the lung. Each tertiary bronchus divides into several bronchioles which further ramify into terminal bronchioles whose number vary from 50-80 in a lobule. Each terminal bronchiole divides into one, two or more respiratory bronchioles; the respiratory bronchioles ramify into alveolar ducts whose number vary from 2-11. The alveolar ducts finally terminate into the alveolar sacs and the alveoli. Thus to summarise the order of the successive divisions of the bronchial tree are primary bronchus, secondary bronchus, tertiary bronchi, bronchioles, terminal bronchioles, respiratory bronchioles (having a diameter 0.5 mm.), alveolar ducts and alveolar sacs and alveoli.

A respiratory bronchiole with its alveolar ducts and the associated alveolar sacs and alveoli together with their blood vessels, nerves, lymphatics and connective tissue constitutes a *lung unit*.

Differences between the intra- and the extra-pulmonary bronchi. The extra-pulmonary bronchi are not strictly cylindrical and they have *flattened membranous posterior walls* due to the deficiency of the *cartilaginous ring-framework* which form the skeleton of the bronchi. The plain muscle fibres do not surround the tube but they partially occupy in the posterior part. The intra-pulmonary bronchi are cylindrical because they are surrounded all around by irregularly placed cartilaginous plates; thus the cartilaginous plates replace the cartilaginous rings within the lung. The plain muscle fibres completely surround them in an irregular pattern; moreover the cartilages completely disappear when the diameter of the bronchiole measures 1 mm.

Main bronchopulmonary segments. *Right lung.* The right lung consists of 10 main bronchopulmonary segments and they are distributed as follows:—

Upper lobe. 3 Bronchopulmonary segments—Apical, anterior and posterior.

Middle lobe. 2 Bronchopulmonary segments—medial and lateral.

Lower lobe. 5 Bronchopalmonary segments—Apical, medial, lateral, anterior and posterior basal.

Left lung. The bronchopulmonary segments of the left lung are distributed as follows:—

Upper lobe. 5 Bronchopulmonary segments—Apical, anterior, posterior, superior and inferior lingular.

Lower lobe. 4 *Bronchopulmonary segments—Apical, anterior,* posterior and lateral basal.

Applied Anatomy. The bronchopulmonary segments are *surgical units* and therefore they are resectable surgically. They are greatly concerned in the occurence and spread of the diseases in the lung. Some of the infective diseases remain confined to an individual segment while some others such as the tuberculosis of the lung breaks through the segmental barrier to spread to the adjacent segment. Carcinoma of the lung also breaks through the segmental barrier. The knowledge of the topographical directions of the bronchi is utilised in postural drainage and in lipiodol injection for a siagraphy for diagnostic purposes. The middle lobe bronchus becomes frequently compressed by the surrounding enlarged lymph nodes or by other external pressure. The lateral and the posterior bronchopulmonary segments in the upper lobe are the frequent sites for lung abscess.

Structure. The trachea and the extrapulmonary bronchi are similar in structure and their skeletal framework is formed by a set of interrupted and incomplete cartilaginous rings which are sandwitched between two layers of fibrous membrane containing variable amount of muscular and elastic tissues, and the tubular structure thus formed is *covered internally by mucous membrane having a lining of columnar ciliated epithelium.*

The incomplete *cartilaginous rings* of the trachea vary in number from 16 to 2[illegible] and structurally each of them is a *hyaline cartilage*. Each cartilaginous ring form a little more than two-thirds of a circle and is deficient posteriorly and thus th trachea appears to be flattened posteriorly. The posterior deficiency is bridge over by a membrane of fibro-muscular tissue. Each ring is flattened externall

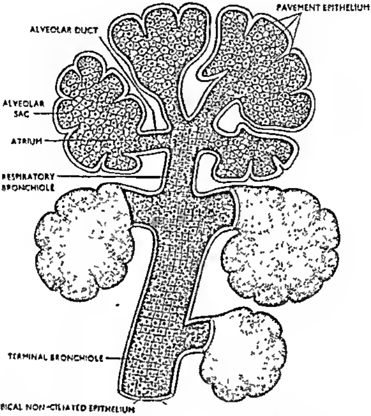


Fig. 738. The terminal bronchiole with its ramifications and structure.

but is convex internally; at one end or the other some of the cartilages may be seen to be bifurcating. *The first cartilaginous ring is broader and complete and is connected to the cricoid cartilage by the cricotracheal ligament and occasionally it is partially continuous with the cricoid cartilage. The last ring is adapted to the bifurcation of the trachea and presents a hook-like process, the carina, which curves backwards and upwards from the middle of its lower border.*

The *fibrous membranes* of the trachea form two tubular sheets which enclose the tracheal rings between them. Posteriorly between the ends of the tracheal rings and in the interval between the adjacent rings the two fibrous membranes fuse to form a single layer. They consist of collagenous and elastic fibres which cross each other to form the membrane. They contain variable amount of non-striated muscle fibres between them posteriorly which consist of longitudinal and transverse fibres. The transverse fibres (trachealis muscle) are deeper or internal to the longitudinal fibres.

The *mucous membrane* consists of areolar type of connective tissue, basement membrane and the columnar ciliated epithelium from without inwards. The areolar layer contains some lymphoid tissue and the mucous secreting glands and a few longitudinal elastic fibres which lie deep to the basement membrane.

Beneath the mucous coat there is a loose connective tissue layer the *submucous layer* which contains blood vessels, nerves and lymphatics.

THE PLAN OF THE THORACIC CAVITY

The cavity enclosed by the ribs with their cartilages, the sternum and the thoracic vertebrae, as viewed in the skeleton, in otherwords the cavity of the thoracic cage, is seen to be "open" below so as to form a continuous thoraco-abdominal cavity. In the recent state, the diaphragm muscle is seen to form a musculo-tendinous partition which subdivides the continuous thoraco-abdominal cavity into two compartments, upper thoracic cavity and lower abdominal cavity. The skeletal deficiencies of the thoracic wall, that is, the intercostal spaces, are bridged over by soft tissues and the walling attains its perfection by the pleural membrane which makes a continuous inner lining of the thoracic walls in each half of the thoracic cavity and then spread between the anterior and the posterior walls separately, either directly or indirectly, maintaining the continuity all the time in each half of the thoracic cavity. Thus two pleural sacs are formed, one on each side, completely separated from each other and closed on all sides. The two pleural sacs are formed, one on each half of the thoracic cavity, which are oriented in such a fashion that they become closer to each other both anteriorly as well as posteriorly but they are separated from each other by wide intervals in the intermediate positions where they enclose the heart. Thus the two pleural sacs, one on each side, enclose a space between the *mediastinum*, a provision which makes room for the heart with its great vessels, for them, and a thoroughfare for the structures going up and down. Thus the thoracic cavity is subdivided into right and left pleural cavities, into which the corresponding lung is invaginated from the medial side, and the mediastinum.

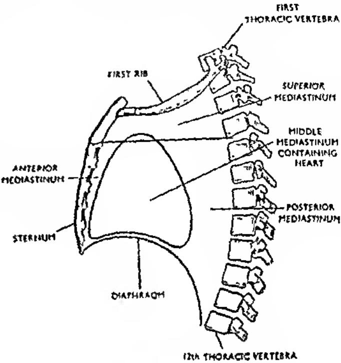


Fig 739. The mediastinum as seen from the side.

The pleural cavities. Each pleural cavity is a closed compartment within each half of the thoracic cavity and is outlined by a serous membrane known as the **pleura** and the space within the cavity is almost fully occupied by the corresponding lung which is invaginated into it.

Boundary. Each cavity is bounded in front by the pleura covering the inner aspect of the costal cartilage and the lateral portion of the sternum. *Posteriorly* it is bounded by the pleura covering the inner aspects of the ribs and intercostal muscles medial to their angles. Inferiorly it is bounded by the pleura covering the corresponding cupola of the diaphragm, *medialy* by pleura covering the bodies of the thoracic vertebrae and the mediastinum and *laterally* it is bounded by the pleura covering the inner aspects of the ribs and intercostal muscles lateral to the angle of the ribs.

The recesses of the pleural cavity. From the medial side, the corresponding lung invaginates into the pleural cavity which is almost fully occupied by it. Thus the pleura which outlined the walls of the pleural cavity also invests the lung and then covers the structures of the lung root from in front and behind and is thus subdivided into pulmonary or visceral and parietal pleurae (See the accompanying diagram)

which are continuous with each other. At certain lines the reflexions of pleura between two different walls meet at an acute angle where, normally in quiet respiration, the margins of the lungs fail to reach and these spaces opposite these acute angles are known as *pleural recesses.* Thus each pleural cavity may be conveniently divided into a *main cavity* which is occupied by the lung and into *pleural recesses* where the lung fails to reach in quiet or even in deep inspirations. The pleural recesses are *retro-oesophageal*, *costo-diaphragmatic* and *costo-mediastinal.* These recesses have been discribed along with the description of the parietal pleura.

THE PLEURA

The **pleura** is a thin, delicate, serous membrane which invests the lungs as well as the inner surfaces of the different walls of the corresponding thoracic cavity.

Each lung is invaginated into the corresponding pleural sac and for this the lung gets an investment from the pleura. Thus the pleura which outlined the different parieties of each half of the thoracic cavity, is seen to cover the lung as well. Thus for descriptive purposes the pleura may be divided into visceral or pulmonary pleura and into parietal pleura, both of which are continuous with each other.

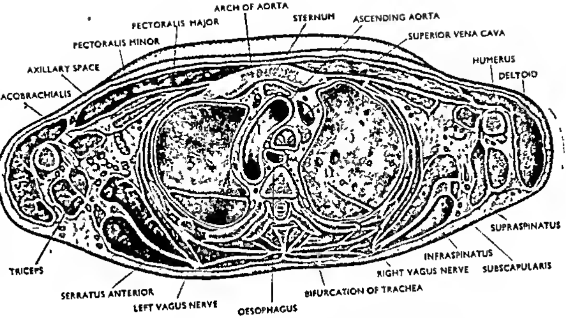
The **Pulmonary Pleura.** It almost completely invests the lungs including the fissures except the hilum and along the line of attachment of the pulmonary ligament. It is inseparably connected with the surface of the lungs and gives it a smooth and glistening appearance.

The **parietal pleura** has been given different names according as it covers the different walls of the pleural cavity. Thus the portion covering the inner surface of the ribs is called the *costal pleura*, that covering the mediastinum, the *mediastinal pleura*, and that covering the diaphragm, the *diaphragmatic pleura.* That portion which extends into the neck so as to cover the aepx of the lung is called the *cervical pleura.*

Costal Pleura. It covers the inner surface of the ribs and the intercostalis intimi muscles. It is loosely attached to the inner surface of the ribs that can be easily separated from them. Anteriorly, after being attached to the back of the sternum it is continuous with the mediastinal pleura. Posteriorly, it covers the sympathetic trunk, the posterior intercostal arteries and the vertebral column and then is continuous with the mediastinal and the pulmonary pleurae. Inferiorly, after being attached to the inner surface of the costal cartilages and the ribs, it is reflected on to the diaphragm to form the diaphragmatic pleura. Superiorly, it is continuous with the cervical pleura.

Anteriorly, the line of attachment of the costal pleura is as follows: It begins from behind the sterno-clavicular articulation and descends medially and downwards to the angle of the sternum where both the pleurae come in contact with each other. Then they descend in close contact up to the level of the fourth costal cartilage beyond which the reflection varies on the two sides. On the right side from this level it descends vertically downwards to the back of the xiphoid process of the sternum and then turns laterally and downwards; on the left side from the level of the fourth costal cartilage it curves laterally and downwards lying at a close distance from the lateral margin of the sternum to reach the back of the sixth costal cartilage from where it curves backwards and laterally.

Inferiorly, the line of attachment on both sides is almost the same except that the left pleura descends a little more than the right pleura. On the right side from behind the xiphoid process it curves backwards and laterally and downwards behind the seventh costal cartilage and crosses the tenth rib opposite the mid-axillary line, then ascends backwards aod laterally and after being attached to the inner surface of the twelfth rib it reaches the level of the spine of the twelfth thoracic vertebra and is then reflected on to the diaphragm. On the left side from behind the sixth costal cartilage it sweeps backwards, laterally and downwards and the rest of its course is the same as on the right side.



A transverse section of the thorax opposite the fourth thoracic vertebra. With kind permission from: Lederle Laboratories Ltd. Drawn by Mr. Paul Peck.

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Mediastinal Pleura. It covers the lateral aspect of the mediastinum or the interpleural space. Anteriorly, it is attached to the back of the sternum where it is continuous with the costal pleura. Posteriorly it is fixed in front of the vertebral column. Above the root of the lung it forms a complete septum between the sternum

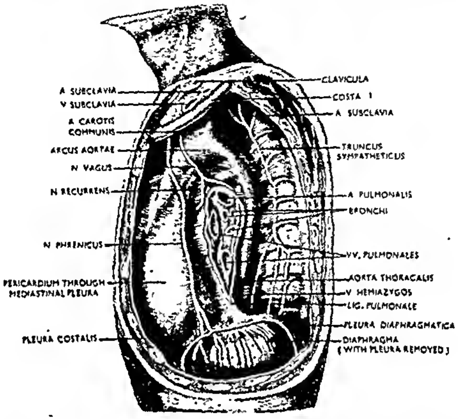


Fig. 740. The structures on the left surface of the mediastinum. With kind permission from Callander: Surgical Anatomy: W. D. Saunders Company, Philadelphia and London.

in front and the vertebral column behind. Opposite the root of the lung it is reflected on to it and is continuous with the pulmonary pleura. Below the root of the lung it forms two layers which stretch from the oesophagus to the mediastinal surface of the lung and constitutes the *pulmonary ligament* which ends below in a free border. The *pumlonary ligament* is formed by that portion of the mediastinal pleura which stretches from the oesophagus to the mediastinal surface of the lung below its root and then is continuous with the pulmonary pleura which again after investing the lung and posterior aspect of the root extends to the lateral edge of the oesophagus blending with the former and thus constituting the *pulmonary ligament.*

Behind the root of the lung and the pulmonary ligament the right mediastinal pleura passes to the front of the oesophagus, then behind it and then passes on to the front of the bodies of the vertebrae and finally becomes continuous with the costal pleura. The left mediastinal pleura similarly invests the oesopbagus, covers the descending thoracic aorta and then passes on to the vertebral bodies. Extending from above the diaphragm upto the level of the fourth thoracic vertebra the right and the left mediastinal pleurae meet each other so as to form a partition between the two pleural sacs. In this situation, on each side, the space enclosed by the mediastinal pleura behind the oesophagus is known as the *retro-oesophageal pleural recess.*

On the right side the mediastinal pleura is in relation to the right innominate vein, azygos vein, superior vena cava, right phrenic and right vagus nerves, trachea and the oesophagus. On the left side it is in relation to the arch of the aorta, left

subclavian and the left common carotid arteries, the left vagus and the left phrenic nerves and the oesophagus and the trachea.

Diaphragmatic Pleura. It covers the upper surface of the diaphragm. Medially it is continuous with the mediastinal pleura, laterally it is continuous with the costal pleura. The lower margin of the lung in quiet respiration does not reach as low as the lowest limit of the pleural reflection. Thus a recess exists between the reflections of the costal and diaphragmatic pleurae which is called the *costo-diaphragmatic recess*. It forms the most dependent part of the corresponding pleural sac.

Cervical Pleura (cupola of the pleura). It covers the apex of the lung and extends into the root of the neck. It begins as a continuation of the costal pleura from opposite the inner border of the first rib and covering the apex of the lung descends downwards and medially on the side of the trachea and is then continuous with the mediastinal pleura. The summit of the cervical pleura reaches as high as the neck of the first rib and is about 1¼ inches distant from the junction of middle with the medial-third of the clavicle. The cervical pleura is strengthened by a dome-shaped expansion of fascia which stretches from the inner border of the first rib to the transverse process of the seventh cervical vertebra called the supra-pleural membrane (Sibson's fascia). Just below the summit the cervical pleura comes in direct contact with the subclavian artery.

Thus it is evident from the distribution of the pleura that it is completely invaginating the lung and each half of the thoracic cavity is completely shut off from the other by the mediastinal pleura and the mediastinum and each pleura makes a complete pleural sac into which the lung is invaginated being placed outside the pleural cavity.

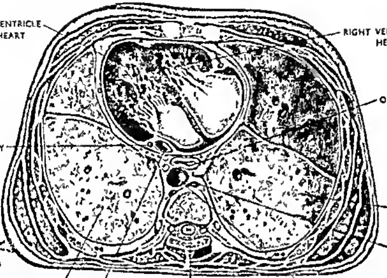
Costo-diaphragmatic recess or sinus. The costo-diaphragmatic recess is a pocket-like blind diverticulum or recess of the corresponding pleural sac and is formed between the reflections of the costal and diaphragmatic pleura. It is situated below the level of the inferior margin of the lung. In quiet respiration the inferior margin of the lung does not extend so far to the bottom of the recess; thus a blind space remains between the inferior margin of the lung and the bottom of the recess which forms an additional provision for the lung to expand in times of need. This recess is related below to the medial end of the spleen on the left side, from which it is separated by the diaphragm muscle. On the right side it is related below to the bare area of the liver being separated from it by the diaphragm. It is the most dependent part of the corresponding pleural sac, hence any pus or fluid accumulating into the pleural cavity usually tends to gravitate into this space. It lies opposite to the 10th, 11th and 12th ribs.

Costo-mediastinal recess or sinus. It is a narrow space formed between the reflection of the costal and mediastinal pleura. In normal respiration the thin anterior margin of the lung does not reach so far upto this space.

Structure of pleura. The pulmonary and the parietal pleurae differ from each other in structure in their details as noted below:

The pulmonary pleura forms the connective tissue capsule of the lung and consist of four layers structurally. The first or the outermost layer is the serous layer, the second is the collagenous layer, the third layer is the layer of elastic membrane and the fourth or the deepest layer is the sub-pleural areolar layer.

The *outermost serous layer* forms a thin membrane of mesothelial cells which rests on the subjacent *collagenous layer* consisting of a felt-work of collagenous fibres predominently with a few elastic fibres embedded in it. The third layer consists of elastic fibres which condense to form a membrane, the *layer of elastic membrane*. The fourth or the deepest layer overlies lung alveoli and consists of loose areolar tissue, the *sub-pleural areolar layer*. Thin septa carrying blood vessels, nerves and lymphatics from the sub-pleural areolar layer pass into the lung and incompletely surround the lobules of the luog.



The transverse section of the thorax opposite the level of the eighth thoracic vertebra. With kind permission from: Lederle Laboratories Ltd. Drawn by Mr. Paul Peck. [To face page 925]

The **parietal pleura** consists of three layers, *outer sub-serous layer*, consisting of areolar tissue, *intermediate collagenous layer* which contains some elastic fibres and the *inner serous layer* consisting of mesothelial cells.

Each lung is invaginated into the corresponding pleural sac and for this the lung gets an investment from the pleura. Thus the pleura which outlined different parieties of each half of the thoracic cavity, is seen to cover the lung as well. Thus for descriptive purposes the pleura may be divided into visceral or pulmonary pleura and into parietal pleura, both of which are continuous with each other.

Vascular and nerve supply. The visceral pleura is supplied by the bronchial artery. The sympathetic nerve supply the visceral pleura. The parietal pleura is supplied by the intercostal, pericardiacophrenic, musculophrenic and phrenic arteries. The nerves are the phrenic and the intercostal.

THE MEDIASTINUM

The **mediastinum** is the region between the two pleural sacs. It is bounded on each side by the mediastinal pleura, in front by the sternum and behind by the bodies of the thoracic vertebrae.

For the purposes of description it is divided into superior and inferior mediastinums by means of an imaginary plane passing from the sternal angle to the lower border of the fourth thoracic vertebra. The latter is further subdivided into anterior, posterior and middle compartments by the pericardium containing the heart.

Superior mediastinum. BOUNDARY. It is bounded in front by the manubrium sterni, behind by the upper four thoracic vertebrae, laterally by the mediastinal pleura, and below by the plane passing from the sternal angle to the lower border of the fourth thoracic vertebra.

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Muscles. Origin of the sternohyoid and sternothyroid and the longus cervicis.

Arteries. The aortic arch with its three great vessels i.e. brachiocephalic (innominate), left common carotid and left subclavian.

Veins. The brachiocephalic (innominate) vein, the upper part of the superior vena cava, and the arch of the azygos vein.

Nerves. The vagus, phrenic, left recurrent laryngeal and cardiac.

Lymphatics. Thoracic and right lymphatic ducts.

Other structures. Oesophagus, trachea, remains of the thymus gland and lymph nodes.

Middle mediastinum. The middle mediastinum is occupied by the pericardium enclosing the heart with its big vessels, ascending aorta and the pulmonary trunk, and the left bronchus, the phrenic nerve and the pericardiacophrenic vessels.

Anterior mediastinum. It is bounded in front by the body of the sternum, behind by the pericardium, laterally by the mediastinal pleura, below by the diaphragm and above by the oblique plane. It contains a few loose areolar tissue, sternopericardial ligaments, a few arterial twigs, lymphatic nodes and lymphatic vessels.

Posterior mediastinum. It lies behind the pericardium and is bounded in front by the pericardium and the posterior surface of the diaphragm, behind by the lower eight thoracic vertebrae, laterally by the mediastinal pleura, below by the diaphragm and above by the oblique plane.

Contents—

(1) The descending thoracic aorta and its branches.
(2) The oesophagus.
(3) The azygos, superior and inferior hemiazygos veins.
(4) The vagi nerves.
(5) The thoracic duct and lymph nodes.
(6) The splanchnic nerves. (The greater, lesser and the lowest).

Disposition of the structures. The descending thoracic aorta runs downwards along the left side of the front of the thoracic vertebrae. The oesophagus at first runs downwards along the right side of the descending thoracic aorta and immediately above the oesophageal opening in the diaphragm it crosses in front of the descending thoracic aorta. The right and the left vagus nerves form the oesophageal plexus on the oesophagus, the left nerve being placed in front but the right nerve behind it. The azygos vein and the thoracic duct both lie behind the oesophagus and the descending thoracic aorta, the thoracic duct being placed on the

Fig. 741. The thoracic cage with the viscera in situ together with their surface markings. From the Anatomical Museum Calcutta Medical College; with kind permission from the Govt. of West Bengal and the Prof. of Anatomy.

left side of the azygos vein. The splanchnic nerves descend downwards along the sides of the bodies of the thoracic vertebrae. The superior and the inferior hemiazygos veins lie behind the descending thoracic aorta. The right aortic intercostal arteries cross the front of the vertebral column in series transversely from the left to the right side and form the posterior-most structures.

THE LUNGS

Each lung is conical in shape and presents a base; an apex; two surfaces, lateral and medial; and three borders, anterior, posterior and inferior.

The base of the lung is deeply concave and rests on the diaphragm which separates the right lung from the right lobe of the liver and the left lung from the left lobe of the liver, stomach and the spleen.

The apex occupies the cervical dome of the pleura. It is rounded in shape and extends upto the level of the neck of the first rib posteriorly, and 1 to 1½ inches above the clavicle anteriorly.

Relations. It is covered by the supra-pleural membrane and the cervical dome of the pleura. Posteriorly opposite the neck of the first rib the apex of the lung is related to the sympathetic trunk, superior intercostal artery, first posterior intercostal vein and a branch from the first thoracic nerve that ascends upwards to join the brachial plexus of nerves, being separated from these structures by the costal pleura and the suprapleural membrane. Anteriorly the apex is related to the right subclavian artery which produces an impression on this part of the lung; the apex of the left lung is related to the left subclavian artery and lying in front of it is the left brachiocephalic vein both of which produce impression on the lung. Anteromedially both the apices are related to trachea, vagus nerve and oesophagus but these structures do not produce any impression on the lung.

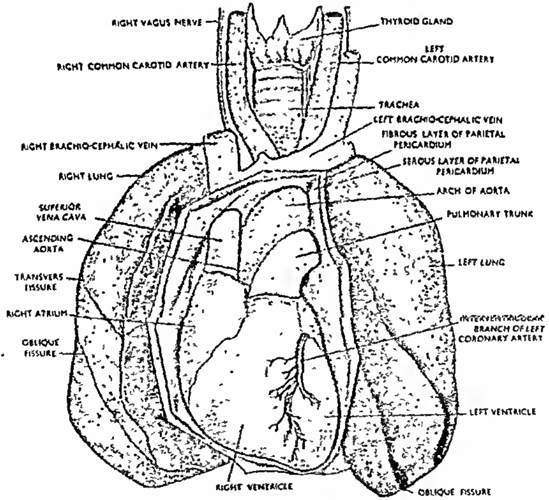


Fig. 742. The heart and the lungs as seen from the front. The pericardium has been exposed.

Segmentally the apex of the lung consists of the *apical, anterior* and the *posterior segments.*

The **lateral surface** is large and convex. It is in contact with the parietal pleura covering the inner surfaces of the ribs and the intercostal muscles. In the

mid clavicular line the upper six ribs, in the mid-axillary line the upper eight ribs and opposite the seapuler line upper ten ribs come into relation with this surface.

The **medial surface** is subdivided into a vertebral area, which is adapted to the sides of the bodies of the thoracic vertebrae, and a mediastinal area, related to the mediastinal structures. The mediastinal area presents the hilus, where the bronchi, vessels, nerves, and lymphatics enter and leave the substance of the lung, and some of the impressions of the mediastinal structures.

The hilus. It is a depressed area on the mediastinal surface of the lung, situated above and behind the cardiac impression, through which the bronchi, the bronchial vessels, pulmonary vessels, lymphatics and the nerves either enter or leave the lung.

On the left lung the hilus is raquette-shaped and extends over both its lobes.

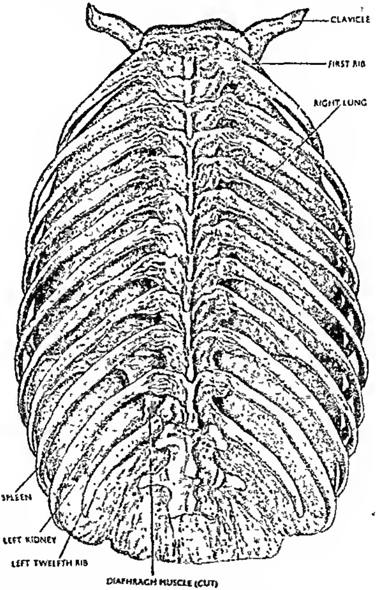


Fig. 743. The thoracic cage with the lungs. Seen from behind. The intercostal spaces have been cleared of the soft tissues. With kind permission from the Govt. of West Bengal and the Prof. of Anatomy Calcutta Medical College.

On the right lung the hilus is a four-sided area which extends over all the three lobes. The hilus on the right side is shorter in height that the left one.

The root. The structures that enter and leave the lung at its hilus are called the root of the lung. The root of the lung is comparable to the roots of a tree. As the roots of a tree firmly anchor the tree into the earth so the root of the lung fixes it to the body firmly. The roots in a tree provide nutrition to it so in the lungs the root, in someway, is concerned in its nourishment.

Structures of the root. The following structures compose the root of the lung.

(*i*) Bronchus (Hyparterial and eparterial on the right side and hyparterial on the left side.)
(*ii*) Bronchial artery and vein.
(*iii*) Pulmonary artery.
(*iv*) Two pulmonary veins.
(*v*) Pulmonary plexus of nerves.
(*vi*) Lymphatics and the bronchopulmonary lymph nodes.

Arrangement of the structures at the root. The arrangement of the structures at the root of the lung differs on the two sides from above downwards; *in the right lung* the arrangement is, eparterial bronchus, pulmonary artery, hyparterial bronchus and the lower pulmonary vein; *on the left side* the arrangement is, pulmonary artery,

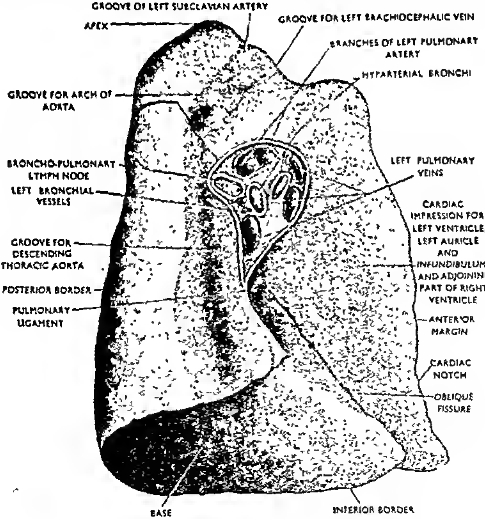


Fig. 744. The medial surface of the left lung.

bronchus (hyparterial), lower pulmonary vein. However, from before backward, the arrangement is same on both sides such as, upper pulmonary vein in front, pulmonary artery in the middle and the bronchus behind. The bronchial vessels lie posterior to the bronchus.

Relations of the root of the lung. Each root of the lung lies opposite the bodies of the fifth to the sventh thoracic vertebrae (vertebral level). The phrenic nerve, pericardiacophrenic vessels and the anterior pulmonary plexus of nerves lie anteriorly whereas the vagus nerve and the posterior pulmonary plexus of nerves lie posteriorly on both sides. The pulmonary ligament lies inferiorly on both sides. On the right side the superior vena cava and the right atrium of heart form additional anterior relation and the arch of the azygos vein lies above the root of the right lung. On the left side the descending thoracic aorta forms the additional posterior relation and the arch of the aorta lies above the root of the left lung.

The **anterior border** begins at the apex and is thin and sharp and on the right side it is less oblique; it presents a notch or indentation known as the *cardiac notch* on the left side.

The **posterior border** is thick, broad and rounded and occupies the hollow of the side of the vertebral column.

The **inferior border** limits the base. It is thin and sharp.

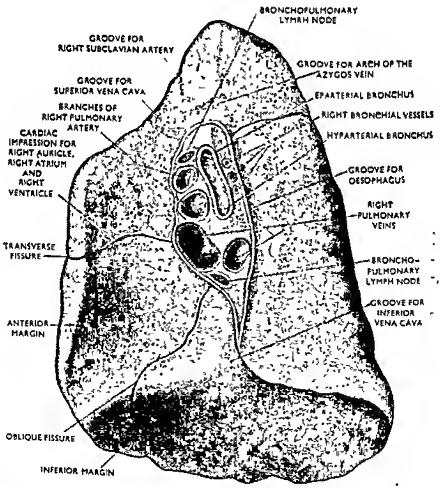


Fig. 745. The medial surface of the right lung.

The relations of the medial surface of the right lung. The *vertebral area* is related to the bodies of thoracic vertebrae, posterior intercostal arteries and the splanchnic nerves on both the sides. In the *mediastinal area*, below and anterior to the hilum there is a depression the *cardial impression* caused by the right atrium, right auricle and the part of the right ventricle of the heart. In front and above the root of the lung there is a shallow depression for the superior vena cava. The upper continuation of this groove lodges the right brachiocephalic (innominate) vein. A narrow deep groove above the hilum lodges the arch of the azygos vein. Behind the hilum there is a narrow vertical groove for the oesophagus. A shallow groove in front of the apex lodges the right subclavian artery. Immediately in front of the lower end of the pulmonary ligament is a groove produced by the inferior vena cava before it enters the right atrium of the heart. The area above the arch of the azygos vein is in relation to trachea, vagus nerve and oesophagus but these structures do not produce any impression in this part.

The relations of the medial surface of the left lung. Below and in front of the hilum is a wide groove which lodges the left atrium and its auricle and the infundibulum of the right ventricle of the heart. A broad groove above the hilum is produced by the arch of the aorta. A vertical wide groove behind the hilum is caused by the descending thoracic aorta. From the anterior part of the depression for the aortic arch a narrow groove runs vertically upwards and lodges the left subclavian artery. In front of the groove for the subclavian artery there is a shallow groove for the brachiocephalic (innominate) vein. Immediately behind the lower end of the pulmonary ligament and in front of the groove for the descending thoracic aorta there is a slight notch for the oesophagus. The area posterior to the groove for the subclavian artery is related to the oesophagus and the thoracic duct but no impressions are produced by them.

The lobes and fissures of the lung. The right lung is divided into three lobes by two fissures, oblique and transverse. The oblique fissure takes a similar course to that of the left lung. The horizontal or the transverse fissure begins at the anterior border opposite the level of the fourth costal cartilage and extends laterally and slightly upwards to meet the oblique fissure opposite the mid-axillary line. The portion of the lung which lies below the oblique fissure constitutes the inferior lobe. The portion above the horizontal fissure is the superior lobe and the portion in between the horizontal and oblique fissures, constitutes the middle lobe. *The main bronchus on the right side gives off three primary buds, all of which remain separated from each other and thus the right lung has three lobes.* Sometimes the upper lobe may be incompletely divided into medial and lateral parts by a fissure containing the azygos vein. The portion demarcated by the azygos vein is known as the azygos lobe of the lung.

The left lung is divided into two lobes, superior and inferior, by the oblique fissure which cuts the posterior border two and a half inches below the apex of the lung at the level of the interval between the third and the fourth thoracic spines 2 cm. lateral to the median plane, and begins on the medial surface above and behind the hilum, and descending downwards and forwards, the fissure reaches the fifth intercostal space in the midaxillary line and then follows the same space and finally ends in the inferior border of the lung at the sixth costochondral junction about five inches from the median plane. The superior or the upper lobe lies above the oblique fissure whereas the inferior or the lower lobe lies below the oblique fissure. A tongue-shaped projection of the upper lobe below the cardiac notch is known as the *lingula*. *The main bronchus on the left side also provides three primary buds but the upper and the middle buds arise together by a common stem. Hence the left lung has two lobes.* The upper lobe of the left lung thus represent upper and the middle lobes of the right lung.

The differences between the two lungs. (1) The right lung has got three lobes, the left has only two. (2) The right is larger in the proportion of eleven to ten. (3) The right lung is shorter, owing to the upward projection of the dia-

Sub-serous coat. It is formed by a layer of connective tissue containing mostly the elastic fibres and this layer passes inwards between the lobules of the lungs.

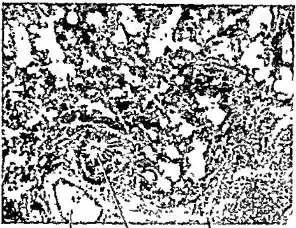


Fig. 746. The low power view of the histological structure of the lung. The slide lent by Dr. K. K. Banerjee Ph. D. (Anat.)

Pulmonary substance. The pulmonary substance consists of lobules containing air cells in association with the respiratory bronchiole together with the blood vessels, nerves and lymphatics. The *respiratory bronchioles* have no cartilages in their walls and they are about ·2 mm. in diameter and each is lined internally by cubical non-ciliated epithelium. Each respiratory bronchiole divides into *alveolar ducts* which terminate into the *atria*, an expanded common chamber, and the latter in turn end into the *air saccules*. The alveolar ducts, atria and air saccules are lined by pavement epithelium.

Each air saccule is separated from the adjacent saccule by a thin-walled septum. Around the thin-walled air saccule the blood vessels form a sheath of capillaries known as the *pulmonary capillaries*.

THE URINARY SYSTEM

THE KIDNEYS

The kidneys are the two compound tubular, excretory glands, situated one on each side of the vertebral column in the paravertebral gutter opposite the dorsilumbar region and behind the parietal peritoneum.

Form and anatomical position. Each kidney is bean-shaped and is placed obliquely with its long axis parallel with the lateral border of the psoas major, its upper pole being about 1 cm. nearer to the vertebral column than its lower pole. Being placed in the paravertebral gutter the anterior surface of each kidney is directed forwards and laterally, its posterior surface backwards and medially and its hilum is directed slightly forwards and medially.

Situation and extent. The kidneys are situated in the lumbar region and extend into hypochondriac, epigastric and umbilical regions. Each occupies the renal angle formed by the twelfth rib and the sacrospinalis muscle opposite the level between the eleventh thoracic and the third lumbar spines. The right kidney is slightly lower (roughly ½ an inch) than the left because of the liver on the right side.

Measurements and weight. Each kidney measures about 4 in. length, 2½ in. breadth and 1½ in. thickness. In weight each is about 4 oz.

Capsules. Each kidney has three capsules, a true capsule, a fatty capsule made up of perirenal fat, and the renal fascia.

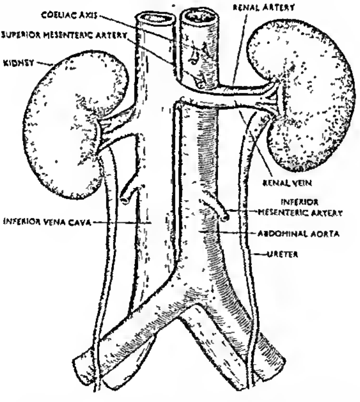


Fig. 747. The kidneys with the great vessels. Seen from the front.

True capsule. It is a fibrous membrane which is closely applied to its surfaces and in health can be easily stripped off from them. Medially it dips into the renal sinus for which it forms a lining and covers the structures of the hilum.

Fatty capsule. It is a specialised layer of fat which is semiliquid in consistency and closely surrounds the kidney within the layers of the renal fascia and intervenes between it and the true capsule. Medially it passes through the hilum into the renal sinus insinuating itself between the renal vessels.

Renal fascia. The renal fascia is an areolar membrane derived from the subperitoneal connective tissue. It divides into two lamellae which enclose the kidney from in front and behind. Laterally it forms a single layer which is continuous with the transversalis fascia. Medially at the hilum the two layers after enclosing the kidney are firmly attached to the renal vessels and the pelvis of the ureter (R. J. Last). Superiorly the two layers are fused together to form a single layer which is continuous with the fibro-areolar tissue on the undersurface of the diaphragm. Inferiorly the two layers merges with the areolar tissue beneath the peritoneum. In between the twn layers of fascia there is a large quantity of fat which is more abundant posteriorly than anteriorly and is known as the *perinephric fat.*

The perinephric fat forms a tight pack round the kidney and is responsible for retaining the kidney in position. Sudden loss of this fat makes its position insecure and being influenced by the respiratory movements it become moveable (moveable kidney) on its pedicle (renal vessels).

Applied Anatomy. The renal fascia being adherent to the renal vessels and the pelvis of the ureter perinephric abscess of one side cannot pass to the opposite side.

Pararenal fat. Pararenal fat or body is a collection of fat around the kidney that lies outside the renal fascia and mostly lies posteriorly behind the renal fascia and between it and the fused lamellae of the lumbar fascia from which the transversus abdominis muscle arises.

Parts for examination. Each kidney presents for examination an upper and a lower pole, an anterior and a posterior surface, a lateral and a medial border, and a hilum which leads into a cavity known as the *renal sinus.*

Renal sinus. The renal sinus is the cavity of the kidney which opens medially at the hilum. The long axis of the sinus corresponds to the long axis of the kidney and it is bounded by thick walls formed by the kidney substance. It is lined by the true capsule of the kidney.

It contains renal pelvis and its calyces, renal artery with its terminal branches, renal vein, nerves, lymphatics and some fat which insinuates between the renal vessels.

The renal pelvis with its calyces occupies most of the area and lies most posteriorly, the renal vein lies in front while the renal artery which breaks up into 3 or 4 branches lies in between the vein and the renal pelvis. One of the branches of the renal artery may pass posterior to the renal pelvis. The lymphatics accompany the pelvis while the sympathetic nerves accompany the renal arteries.

The renal pelvis breaks up into two or three main divisions within the sinus known is the *major* or *greater calyces* which diverge from each other and pass towards the upper and the lower portions of the kidney. Each of the major calyces further divides into *minor* or *lesser calyces.* Each of the lesser calyces terminates in relation to one or two *renal papillae* which protrude into it and the calyces becomes cup-shaped in appearance.

Renal papillae. These are a series of conical elevations on the floor of the sinus and vary from 6 to 15 in number. The blood vessels pierce through the kidney substance in between the renal papillae. The summit of each renal papilla presents numerous minute openings which are the terminal apertures of the renal tubules.

Poles or extremities. The *upper pole* of the kidney is usually larger than the lower pole and lies opposite the level of the eleventh thoracic spine. It is about 1 cm. nearer to the vertebral column than the lower pole which lies opposite the level of the third lumbar spine or 1 inch above the highest point of the iliac crest. The upper pole is slightly higher on the left side than on the right side. Each upper pole

is partially overlapped by the suprarenal gland which also encroaches on to the anterior surface, and the medial border, and rests partly on the diaphragm. The *lower pole* is related to the hepatic flexure and the duodenum on the right side and with the transverse colon and the jejunum on the left side.

Borders. Its *lateral border* is convex in its general outline and on the right side it is related to the ascending colon below and to the liver above. On the left side it is related to the spleen above and to the descending colon below. The lateral border lies at a distance of about 10 cm. from the lumbar spines.

Its *medial border* is concave and is directed forwards and medially. It presents a slit-like cleft in its middle-third known as the *hilum* which gives passage to the renal vessels, nerves, lymphatics and the pelvis of the ureter. The renal vein lies in front, artery in the middle and the pelvis of the ureter below and behind—one of the arteries lies behind the pelvis; nerves accompany the artery and the lymphatics accompany the vein.

The hilum on the right side lies just below the transpyloric plane (plane opposite the first lumbar spine) and on the left side just above it. The medial border is related to the inferior vena cava on the right side and with the duodenojejunal flexure, inferior mesenteric vein and the left suprarenal gland on the left side.

Surfaces. The *anterior surface* is convex and is directed forwards and laterally. The *posterior surface* is flat and is directed backwards and medially.

Relations. Anterior surface of the left kidney. The anterior surface of the left kidney, over a small area opposite its medial margin above the hilum, is in relation to the left suprarenal gland. The upper two-thirds of the lateral half is related to the spleen. Opposite the hilum, the anterior surface is related to the tail of the pancreas and the splenic vessels. Above the pancreatic area and between the suprarenal and the splenic areas, is the gastric impression which comes into relation with the

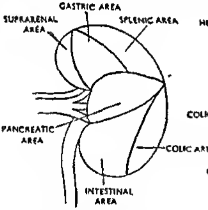


Fig. 748. The relations of the anterior surface of left kidney. (Diagrammatic).

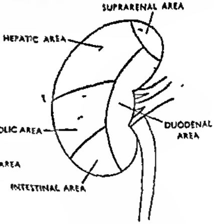


Fig. 749. The relations of the anterior surface of the right kidney. (Diagrammatic).

postero-inferior surface of the stomach being separated by the peritoneum of the lesser sac. Below the pancreatic and the splenic areas, the lateral part of the anterior surface is related to the left colic flexure while its medial part is related to some coils is the small intestine (jejunum). The gastric, splenic and the jejunal areas are covered by peritoneum. The gastric area is covered by peritoneum of the lesser sac whereas the splenic and the intestinal areas are covered by the peritoneum of the greater sac.

Anterior surface of the right kidney. The upper lateral part of the anterior surface is related to the inferior surface of the right lobe of the liver. The medial margin

adjoining the upper pole is related to the right suprarenal gland. Adjoining the hilum the anterior surface comes into contact with the second part of the duodenum. The lower part of the anterior surface is related to the right colic flexure laterally

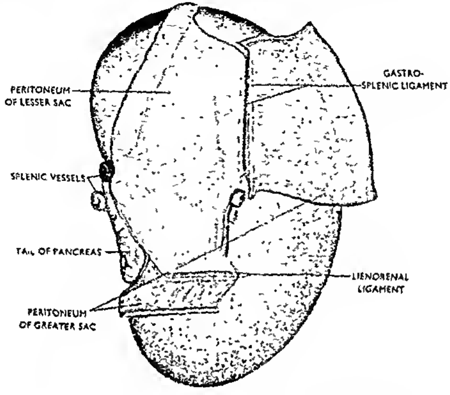


Fig. 750. The ligamentous connections of the left kidney. Diagrammatic (Drawn Dr. K. K. Banerjee Ph.D. (Anat.).

and to some coils of the small intestine medially. The hepatic and the intestinal areas are covered by the peritoneum of the greater sac.

N.B.—The kidney has no true ligaments of its own to keep it in position. It is kept in position by the tight visceral pack around it and by the perinephric fat which effectively anchors it in position. If due to diseases the perinephric fat is absorbed the kidney becomes insecure and it rotates on its own pedicle (renal vessels) giveing rise to a condition known as the floating kidney. The renal fascia being open downwards it usually moves downwards and medially.

Posterior surface. The posterior edge of the upper pole comes into relation with the corresponding suprarenal gland. On both sides, the posterior surface of the kidney lies in relation above with the diaphragm and can be divided into medial and lateral diaphragmatic areas; the medial diaphragmatic area is in relation with the corresponding crus of the diaphragm while the lateral diaphragmatic area is related to the corresponding medial and lateral lumbo-costal arches or the arcuate ligaments. Inferior to the diaphragmatic areas it is related to the psoas major with its covering fascia, quadratus lumborum with the anterior layer of lumbar fascia and the tendon of origin of the transversus abdominis from medial to the lateral side. The sub-costal vessels and nerve, iliohypogastric and the ilioinguinal nerves run obliquely downwards and laterally behind the posterior surface of the kidney in order from above downwards. The subcostal vessels and nerves lie in front of the anterior lamella of lumbar fascia and bound down to it by extra-peritoneal connective tissue whereas the iliohypogastric and the ilioinguinal nerves lie behind the anterior lamella of lumbar fascia between it and the quadratus lumborum muscle. The tips of the first, second and the third lumbar transverse processes are in relation with this surface being separated by the quadratus lumborum. The

eleventh and the twelfth ribs on the left side and only the twelfth rib on the right side are also in relation with the posterior surface of the kidney.

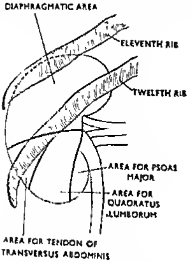


Fig 751. The relations on the posterior surface of left kidney.

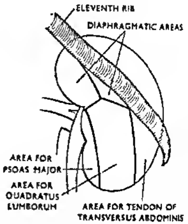


Fig. 752. The relations on the posterior surface of right kidney.

The upper lumbar vessels are separated from the posterior surface of the kidney by the quadratus lumborum.

The costodiaphragmatic recess of pleura is related to the posterior surface of the upper part of the corresponding kidney being separated by the lateral and medial lumbo-costal arches. Sometimes when the diaphragm is deficient this part of the recess may lie in direct contact.

The posterior surface of the kidney is absolutely uncovered by the peritoneum.

Section of the kidney. In a sagittal section of the kidney it is found to consist of an outer paler area known as the *cortex* and an inner darker area known as the *medulla*. In the medullary area six or more longitudinally striated triangular bodies, known as the *pyramid* can be seen. Each pyramid consists of a base which is directed towards the cortex, an apex or papilla directed towards the renal sinus and an intervening portion known as the body. Each of the renal papilla is received in a minor calyx. Sometimes two papillae may be found to open in a calyx minor. The longitudinal striations of the pyramid radiate into the cortex from its base and forms the *medullary rays*. The cortex or the labyrinth of the kidney is granular in appearance. The portion of the labyrinth that projects in the medulla in between the bases of the two pyramids is known as the *renal columns*. The part of the cortex extending between the medullary rays is known as the *cortial rays*. Microscopically the cortex consists of glomeruli and tubules and the medulla contains the collecting tubules.

Blood supply of Kidney. The kidney receives its blood from the renal artery (branch of abdominal aorta) and is drained by the renal vein which terminates into the inferior vena cava.

The veins draining the cortex begin as the *subcapsular stellate veins* which drain into the *interlobular veins*. The interlobular veins drain into the *arciform veins*. The arciform veins are joined by the *venular rectae* from the medulla to form the *interlobar veins* which emerge out at the renal sinus.

Distribution of the artery in the kidney substance. Each renal artery divides into four or five branches before entering into the hilum and lie in between the renal vein in front and the pelvis of the ureter behind except one branch which passes posterior to the pelvis of the ureter. Each subdivision of the renal artery, after

giving some small twigs to the tissues in the renal sinus further subdivides into *lobar branches*, one for each renal papilla. Each lobar artery divides into two or three

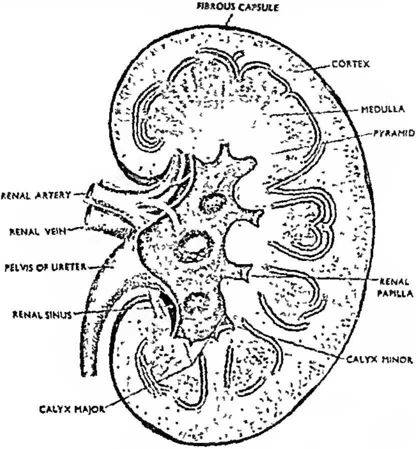


Fig. 753. The longitudinal section of the right kidney.

interlobar branches which enter into the renal substance in between the renal pyramids at the renal column. Reaching the cortico-medullary junction at the base of the renal pyramid each interlobar artery divides at a right-angle into two collateral branches to form an *arterial arcade* (arciform arteries). The arterial arcade gives rise to a series of straight branches known as the *vasa recti* or the *interlobular arteries* which pass into cortex towards the periphery of the kidney. Each vasa recta or the interlobular artery is typically an "end-artery", has no anastomosis with the adjacent interlobular artery and supplies a definite unit of kidney substance known as the *renule*. Each renule consists of a calyx minor with its papilla, the three or four collecting tubules which open into the papilla and a corresponding cortical substance. Thus the kidney substance may be split up into different renules each being controlled by an interlobular artery. Each interlobular artery gives out in series the *afferent vessel to the glomerulus*, a special type of capillary. The glomerulus gives origin to the *efferent vessel*

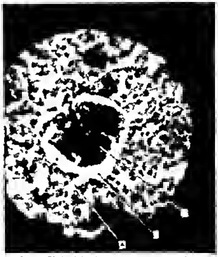


Fig. 754. High power view of a glomerulus.
A=Renal tubule; B=Bowman's capsule. C=The glomerulus

which is thrown out again into capillary bed in between the tubules and is known as *intertubular capillaries* (cortex) which are terminal capillaries.

Close to the medullary region some of the efferent vessels of the glomerulus divide into branches known as *arteriolae rectae* which assume a straighter course as they pass down through the medulla to supply it. Some other efferent vessels from the glomerulus in this region break up into *intertubular capillaries* of the medulla.

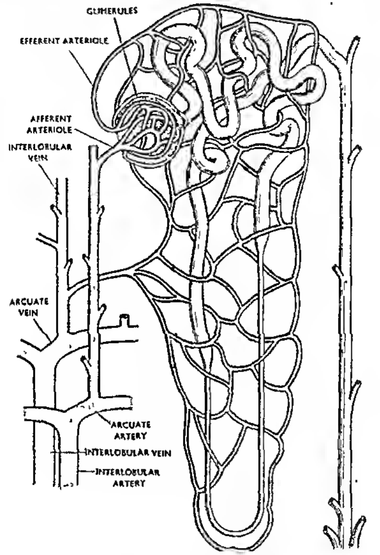


Fig. 755. A Nephron (Diagrammatic).

The intertubular capillaries of the cortex are drained by *interlobular veins* which in turn drain into *interlobar* veins accompanying the interlobar arteries. The veins from the medulla open into the venous arcade accompanying the arterial arcade which terminate into interlobar vein. The interlobar veins unite to form the renal vein.

Applied Anatomy. The interlobular artery being an end artery, in case it is obstructed by an embolus, the renule controlled by it degenerate to form an infraction which is triangular in shape with its base in the cortex and the apex in the papilla.

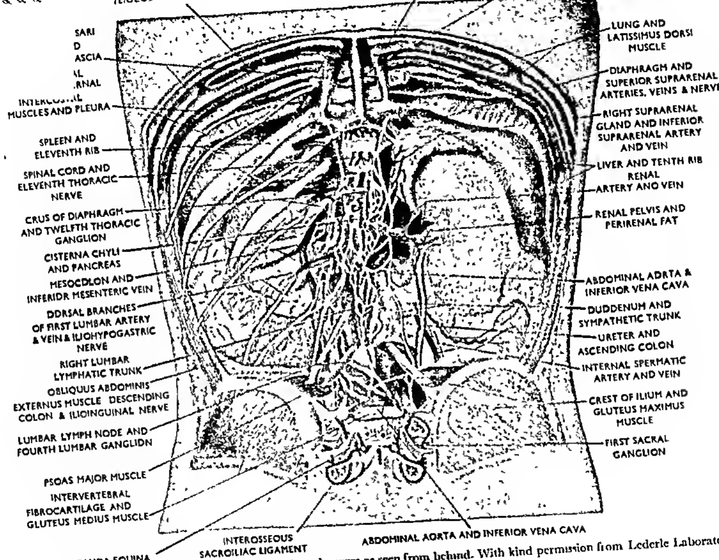


Fig. 756. The kidney together with its vessels and nerves as seen from behind. With kind permission from Lederle Laboratories Ltd. Drawn by Paul Peck

Lymphatics of the kidney. The lymphatics of the kidney consist of superficial and deep lymph vessels. The superficial lymph vessels lie in the true capsule of the kidney and communicate with the lymph spaces between the tubules of the kidney. They emerge at the hilum and end by joining with the deep lymphatics. The deep lymph vessels accompany the renal vessels, communicate with the lymph spaces between the tubules and join with the superficial lymphatics at the hilum. They end in the preaortic group of lymph nodes (lumbar).

Nerve supply of the kidney. It is supplied by sympatheties and parasympathetics (vagus) through coeliac and renal plexuses.

The sympathetic component consists of afferent and efferent fibres. The *sympathetic efferents* are vasomotor in function and their preganglionic fibres are derived from 12th thoracic and 1st lumbar segments of the spinal cord and they pass through all the splanchnic nerves—the fibres of the greater and lesser splanchnic nerves terminate in the coeliac ganglion whereas those in the lowest splanchnic nerve terminate in the renal ganglion at the hilum of the kidney. Postganglionic fibres from these ganglia run along the renal vessels to reach the kidney. The sympathetic afferents pass to the 10th, 11th and 12th thoracic segments. The functions of the parasympathetic supply are still unknown.

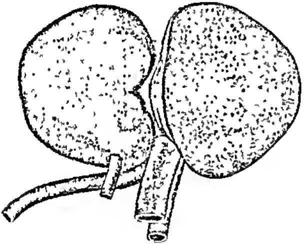


Fig 757. A bilobed kidney. From Anatomical Museum, Calcutta Medical College: with kind permission from the Govt. of West Bengal and the Prof. of Anatomy, Calcutta Medical College.

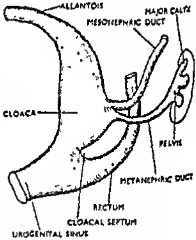


Fig. 758. The cloaca, hind gut and the developing kidney.

Development. The ureter develops as an outgrowth from the caudal end of the mesonephric duct which invades the caudal end of the mesonephric ridge and from the metanephric cap derived from the latter. The mesodermal cells of the mesonephric ridge surrounds the expanded blind end of the mesonephric duct and forms a cap-like investment around it known as the metamesonephric cap.

From the outgrowth of the mesonephric duct the ureter, renal pelvis, calyces and the collecting tubules are formed while the rest of the kidney is formed from the metamesonephric cap.

THE RENAL PELVIS AND THE URETER

The pelvis of the ureter. The funnel-shaped dilated upper end of the ureter is known as the pelvis of the ureter. It is formed within the renal sinus by the union of the two or three calyces majores. Each calyx major is formed by the union of two or three calyces minores, into each of which one or two renal papillae project.

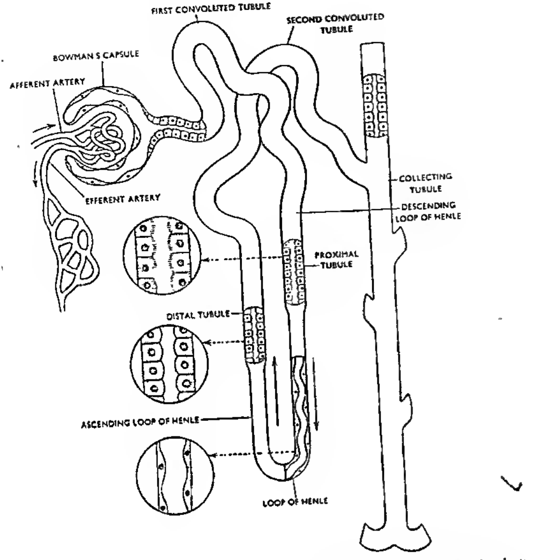


Fig. 759. The epithelial character of the different part of the renal tubules and the collecting ducts.

The ureter. The ureter or the duct of the kidney is about 10 inches long and begins in the renal sinus as the pelvis of the ureter and then diminishing much in calibre it descends vertically downwards through the abdomen and enters the pelvic cavity where after a sinuous course it ends by opening into the lateral angle of the trigone of the urinary bladder. According to its course it is divided into abdominal and pelvic parts.

Abdominal part of the ureter. It begins as a continuation of a funnel-shaped dilatation known as the renal pelvis and descends vertically downwards in front of the psoas major muscle under cover of the parietal peritoneum and is separated from the tips of the transverse processes of the lumbar vertebrae by the same muscle. In this situation it crosses the genitofemoral nerve and itself is crossed by the testicular or ovarian vessels. Then reaching the pelvic brim it crosses either the end of the common iliac artery or the beginning of the external iliac artery and then enters into the pelvic cavity.

On the right side it is covered by the second and the third portions of the duodenum and is crossed by the iliocolic and the right colic arteries and enters the brim of the pelvis beneath enteric mesentery. On the left side it is crossed by the left colic vessels and enters the brim of the pelvis beneath the pelvic mesocolon.

Pelvic portion of ureter. "The pelvic portion of the ureter," as the name implies, is formed by that part of the ureter which is contained within the pelvic cavity and has been described under the following heads:

Extent. It begins as a continuation of its abdominal part from opposite the level of the pelvic brim and by piercing the bladder wall obliquely it ends by opening into the interior of the urinary bladder at the lateral angle of the trigone. It varies from 12.5 to 15 cm. in length.

Course. In its course through the pelvic cavity the pelvic portion of the ureter at first runs downwards, forwards and laterally under cover of the parietal peritoneum upto the level of the ischial spine and then runs medially and forwards upto the base of the urinary bladder and finally pierces the bladder wall obliquely to end into its interior at the lateral angle of the trigone. Thus the course of the ureter within the pelvis can be divided into (1) parietal and (2) intravesical portions. The parietal portion can further be subdivided into first and second portions depending on the general direction it follows. The *first portion* extends from the level of the pelvic brim upto the level of the ischial spine and the *second portion* from the level of the latter upto the point it pierces the bladder wall. Alternatively, though less scientific, the pelvic portion of the ureter can be divided into three parts namely; 1st, 2nd and 3rd; the latter constituting the intravesical part. The intravesical portion is only about ·5·1 cm. in length.

Relations. General (In male). The pelvic portion of the ureter enters the pelvic cavity either by crossing the end of the common iliac or the beginning of the external iliac artery and descends downwards on the lateral wall of the pelvis under cover of the parietal peritoneum and reaches in front of the internal iliac vessels and lies on the medial side of the obturator nerve, obturator, umbilical, inferior vesical and middle rectal arteries. Then it passes downwards and forwards and is crossed in front by the vas deferens opposite the level of the ischial spine and proceeds to reach the base of the bladder. Here it lies above the seminal vesicles, and the vas deferens lies on its medial side. Then it pierces obliquely the musculature of the bladder at the lateral angle of the trigone and ends by opening into the interior of the bladder.

In female. The pelvic portion of the ureter in case of female enters the pelvic cavity either by crossing the end of the common iliac artery or the beginning of the external iliac artery and descends downwards and laterally in front of the internal iliac vessels under cover of the parietal peritoneum and then gaining the medial side of the internal iliac artery it passes beneath the broad ligament and forms the posterior boundary of the ovarian fossa and lies medial to the obturator nerve, the obturator, umbilical (obliterated), inferior vesical and the middle rectal arteries. As it lies on the medial side of the internal iliac artery, the uterine artery descends on its lateral side for about one inch and then crosses in front of it from lateral to the medial side and ascends upwards in between the two layers of the broad ligament. Then the ureter runs further medialwards and forwards to reach the side of the cervix uteri where it lies on the posterior wall of the lateral fornix of the vagina and is at a distance of about 3/4 inch from the cervix uteri. Then for a short distance it comes to lie between the base of the urinary bladder and the anterior vaginal wall. Finally it ends by opening into the bladder at the lateral angle of the trigone.

Peritoneal relation. The intravesical portion is devoid of peritoneum in both the sexes. In the rest of its course in the pelvic wall it is covered by peritoneum medially except where it is crossed by the vas deferens. In the female the portion which intervenes between the base of the urinary bladder and the anterior vaginal wall it is devoid of peritoneal covering; it is also uncovered by peritoneum where it is crossed by the uterine artery; in the rest of its course it is covered by peritoneum medially.

Natural constrictions. The pelvic portion of ureter presents two natural constrictions, one opposite the point where it crosses the end of the common iliac artery and the other just before its termination into the interior of the bladder. In other words, the pelvic portion of the ureter is naturally constricted both at its commencement

.nd at its termination. The intravesical part actually forms the most constricted ›art of the ureter.

Vascular supply. The pelvic part of the ureter is supplied by the superior and nferior vesical and middle rectal arteries (The abdominal part being supplied by enal and testicular or ovarian arteries).

Nerve supply. The pelvic part of the ureter derives its nerve supply from the ıypogastric plexus (The abdominal part being supplied by testicular or ovarian or enal plexus).

Surgical importance. Renal stone is usually obstructed opposite the natural constrictions of the ureter. The ureter is rich in its blood supply and therefore it endures considerable trauma, and healing processes are considerably rapid and perfect. Renal colic due to obstruction by the renal stone in the ureter is usually eferred through the 11th and 12th thoracic and first lumbar nerves.

THE URINARY BLADDER

The urinary bladder is a hollow viscus which acts as a reservoir of urine and is situated behind the symphysis pubis and in front of the rectal ampulla, in male, and n front of the uterus, in the female. The ureter opens into it on either of its base.

Parts for examination. The urinary bladder changes its shape and size according to its contents. When it is empty, it has a base, an apex, and three surfaces —superior and two inferolateral. When it is distended its surfaces are postero-superior, anteroinferior and two lateral. Inferiorly it forms a constricted neck which is continuous with the base of the prostate in case of male and with the urethra n case of female.

The **base** is triangular in shape and is directed downwards and backwards towards the rectum and lies below the line joining the two ureteral openings. It is related to the rectum from which it separated by the recto-vesical pouch, in the male, and the vesico-uterine pouch and the uterus, in the female. Some coils of the ileum usually intervene between it and the rectum in the male and between it and the uterus in the female.

The **apex** is directed towards the symphysis pubis and is connected with the umbilicus by means of a fibrous cord known as the median umbilical ligament (remains of the urachus).

Peritoneal relation. In empty condition, the superior surface of the bladder is covered by peritoneum whereas its inferolateral surfaces are uncovered by peritoneum. In distended condition, the postero-superior surface is covered by peritoneum while the anteroinferior and lateral surfaces are uncovered by peritoneum.

Capacity (Normal):

Average	..	$7\frac{1}{2}$ oz. — 240 cc
Maximum	..	10 oz. — 320
Minimum	..	4 oz. — 120

Ligaments of the bladder. The ligaments of the bladder consist of true and false ligaments.

The **true ligaments** are formed by the condensed mass of fibro-areolar tissue; are more or less fixed in their attachment and they do not change their position the change of the bladder.

The **false ligaments** are formed by the peritoneum; they are not fixed in their hment and they usually change their position with the change of position of /iscera.

True ligaments. (1) *Median umbilical ligament.* It is the fibrous remains of the urachus and connects the apex of the bladder with the anterior abdominal wall.

(2) *Anterior true ligament.* It consists of medial and lateral puboprostatic ligaments and lies on each side of the median plane and is derived from the pelvic fascia. The medial puboprostatic ligament is attached posteriorly to the sheath of the prostate and to the neck of the bladder and anteriorly to the back of the symphysis pubis. The lateral puboprostatic ligament is attached posteriorly to the anterior end of the tendinous arch of the pelvic fascia and is fixed anteriorly to the sheath of the prostate.

(3) *Posterior true ligament.* It is formed by the condensed mass of the fibro-areolar tissue which surrounds the vesical plexus of veins as they pass posteriorly to end into the internal iliac vein.

(4) *Two lateral true ligaments.* Each extends from the side of the neck of the bladder and the sheath of tbe prostate and is attached laterally to the wall of the pelvis.

False ligaments: (1) *Anterior false ligament.* It consists of three folds of peritoneum, one on the median umbilical ligament and two on the obliterated umbilical artery.

(2) *Posterior false ligament.* It is formed by that fold of peritoneum which extends from the bladder to the rectum and then to the sacrum and constitutes the sacro-genital fold.

(3) *Two lateral false ligaments.* Each extends from the side wall of the bladder to the side wall of the pelvis.

Trigone of the bladder. When the bladder is opened it is found that the mucous membrane of the bladder are thrown into folds everywhere except over a triangular area on its posterior wall where the mucous membrane looks smooth, shiny and tense and this area is known as the *trigone of the bladder*. The mucous membrane of the trigone is shiny and smooth because in this part of the bladder it is firmly adherent to the underlying muscular coat and there is no submucous layer.

It is an equilateral triangle, the apex of which is directed downwards and corresponds to the internal urethral orifice. Its lateral angles are pierced by the two ureters, one on each side being placed at a distance of one inch from each other. Its base is formed by an elevated ridge, the *interureteric ridge* which connects the two ureteral openings, one on each side. The orifice of each ureter is guarded by a fold of mucous membrane and is slit-like. The interureteric ridge is a linear prominent elevation of the mucous membrane caused by the prolongation of the longitudinal muscle fibres of the ureters underneath the mucous membrane opposite a line joining the two ureteral openings. The sides of the trigone are formed by drawing imaginary lines from the apex to the corresponding ureteral opening. If a section is made through the mucous coat of the bladder at the upper border of the interureteric ridge it is found that the ureteral muscle fibres are not continuous with those of the bladder but they form a distinct triangular sheet of muscle, the *trigonal muscle* which is spread over the trigonal area and is separable from the muscular wall of the bladder by an areolar bed. The apex of the trigonal muscle descends in the posterior wall of the urethra to the prostatic utricle. On the lateral side of the ureteral opening there is a ridge-like elevation, the *ureteric fold,* which is almost continuous with the interureteric ridge and is formed by the terminal portion of the ureter piercing the wall of the bladder. Immediately above the internal urethral orifice in male, there is a rounded elevation—the *uvula vesicae* formed by the median lobe of the prostate. The uvula vesicae serves as an additional valve-like sphincter in controlling the passage of urine. ~~The trigonal area is not affected by the distention of the bladder and its size and position~~ remain unaltered even in enormous distention.

Applied anatomy. (1) In catheterisation of the ureter, the interureteric ridge serves as a guide under the cystoscope to lead the point of the catheter into the ureteral opening.

(2) Under some pathological condition of the prostate the uvula vesicae becomes unduly prominent so as to cause obstruction in the flow of the urine.

(3) The trigonal area develops from wolffian duct whereas the rest of the bladder develops from the cloaca.

Vascular supply of the bladder. The arteries supplying the bladder are the superior and inferior vesical branches from the anterior trunk of the internal iliac artery and the vesical branches from the inferior gluteal and obturator arteries. In the female it gets additional branches from the uterine and vaginal arteries.

The veins draining the bladder are arranged into vesical and prostatic venous *plexuses which drain into the internal iliac veins. In the female the vesical plexus* represents the vesical and prostatic plexuses of the male.

Nerve supply. It is supplied by both sympathetic and parasympathetic nerves. The sympathetic nerve derives its fibres from the hypogastric plexus of sympathetics whereas the parasympathetic nerves are derived from the second and the third sacral nerves (nervi errigentes). Sympathetic fibres pass from the upper lumbar roots and end in the inferior mesenteric ganglion. *Grey fibres* arising from this ganglion forming the hypogastric nerves ends in a plexus at the base of the bladder.

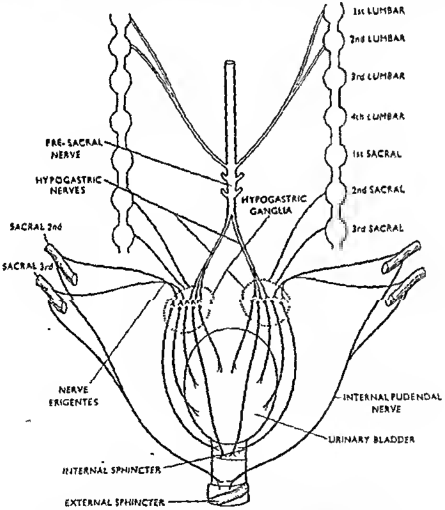


Fig. 760. The innervation of the urinary bladder (Diagrammatic).

The sympathetic nerves are accelatory for the sphincter vesicae and inhibit for its musculature. It also contains afferent fibres which carry painful sensati arising out of the overdistention of the bladder, spasm of the sphincter vesicae ɛ schiaemia of the bladder etc.

The parasympathetic nerves are accelatory for the musculature of the bladder and inhibitory for the sphincter vesicae. It also contains afferent fibres which carry normal physiological sense of distention to the higher centre.

Lymphatics of the bladder. The lymph vessels of the urinary bladder begin in a plexiform network in the submucous coat and collecting vessels from there pass through the muscular coat and terminate into different groups of lymph nodes as follows:

The lymph vessels *from the superior and infero-lateral surfaces* terminate into the external iliac group of lymph nodes in two ways; some end into them directly while others through anterior and lateral visical group of subsidiary lymph nodes..

The lymph vessels *from the neck of the bladder* pass along with the lymph vessels of the prostate to the sacral and median common iliac group of lymph nodes.

The lymph vessels *from the base of* the bladder end into the external and internal group of lymph nodes.

Development. The trigone of the bladder develops from the mesonephic ducts or the wolffian ducts whereas the rest of the bladder develops from the anterior part of the cloaca.

Structure of the bladder. *The wall of the urinary bladder consists of four* coats or tunics and from without inwards they are the serous coat, muscular coat, submucous coat and the mucous coat.

Serous coat. The serous coat of the bladder is derived from the peritoneum which forms a partial investment for this and covers its superior and the upper parts of its lateral surfaces.

Muscular coat. The muscular coat consists of outer and inner longitudinal and intermediate circular fibres.

Outer longitudinal muscular coat. They are spread on both aspects of the bladder and abundantly present opposite the median plane and are less numerous along the sides of the bladder. Anteriorly these fibres are continuous with the muscular layer of the prostate and also they are attached to the back of the body of the pubis. These fibres which are attached to the back of the pubis are called the *pubo-vesical muscles.* Posteriorly some of their fibres blend with the underlying muscular coat of the bladder and some pass backwards to become continuous with the longitudinal muscle fibres of the rectum and are known as *recto-vesical muscles.*

Inner longitudinal fibres. They are less numerous and are mostly present along the inferior aspect of the bladder and are reticular in arrangement. Two bands of oblique fibres arise from behind the ureteral opening and descending downwards are inserted by a fibrous process into the median lobe of the prostate. These bands are called the *muscles of the ureters.* By their action they maintain the oblique direction of the ureter and thus prevent the regurgitation of urine into the ureter.

Intermediate or middle circular fibres. They form the bulk of fibres. Around the urethral orifice they form the sphincter vesicae and then are continued to the muscles of the urethra and the prostate.

Sub-mucous coat. This is a collection of loose areolar tissue which intervenes between the muscular and the mucous coats. This coat is absent opposite the trigonal area. The vessels and nerves branch out in this layer before entering into the mucous coat.

Mucous coat. In empty bladder the greater part of the mucous membrane of the bladder are thrown into folds except over the trigonal area. It is continuous with the mucous membrane of the ureters and the urethra. It is covered by stratified transitional epithelium.

Applied anatomy. Obstruction to the flow of urine, as in cases of the enlarged prostrate or tumor of the bladder, causes hypertrophy of its muscle fibres which are grouped into bundles which interlace one another, and the inner surface of the muscular wall becomes trabeculated. The mucous membrane lining this trabeculated wall bulges out into the trabecular recesses

and forms diverticular recesses into which there may be phosphatic concretion to form encysted stone bladder.

When the bladder is full, injury to the abdomen in the form of kick, fall etc., many cause rupture of the bladder. Fracture of the pelvic bones is often associated with rupture of the bladder. The rupture of the bladder may be intraperitoneal or extraperitoneal according as its parts are involved.

The bladder may be opened extraperitoneally through the retropubic space which is considerably enlarged with its distention.

THE MALE URETHRA

The male urethra is a s-shaped tube which measures about eight inches in length and is divided into three parts, namely, (1) the part traversing the prostate gland—*prostatic urethra*, one and a quarter inches long, (2) the portion piercing the pelvic wall—the *membranous urethra*, three quarter of an inch long and (3) the part lying within the corpus spongiosum penis—the *spongy urethra*, six inches long.

Prostatic portion of the urethra. The prostatic portion of the urethra begins from the internal urethral orifice and traversing through the prostate ends in the membranous part opposite the apex of the prostate gland. It is almost vertical in direction and is fusiform in shape. It is the widest and the most dilatable part of the urethra and measures about one and one-fourth inches in length. In a section through the prostatic urethra it is seen to present a median elevated ridge known as the *urethral crest*. The urethral crest which is formed by the elevations of the mucous membrane and the underlying tissue, divides the prostatic urethra into two lateral recesses, the *prostatic sinus* into which the prostatic ducts open. Over the middle of the urethral crest there is a localised rounded thickening known as the *colliculus seminalis*. At the summit of the colliculus seminalis there is a blind opening which extends deeply for about half an inch and is known as the *prostatic utricle*. The ejaculatory duct formed by the union of the vas deferens and duct of the seminal vesicle opens by a small orifice on each side of the prostatic utricle. Upto the opening of the ejaculatory duct it is lined with transitional epithelium but below that with columnar epithelium. The prostatic utricle represents the vagina and uterus of female in the male.

Development. The upper part of the prostatic portion of the urethra upto the openings of the ejaculatory ducts, develops from the lower end of the mesonephric duct (Wolffian duct) while its lower part is developed from that portion of the urogenital sinus which is formed by the cloaca.

Membranons portion of the urethra. This is shortest portion of the male urethra and lies in between the superior and the inferior layers of the urogenital diaphragm. It begins from the apex of the prostate and ends in the bulb of the urethra by piercing the perineal membrane about one inch below and behind the symphysis pubis. It is directed downwards and forwards with a slight concavity forwards and its posterior wall is shorter than its anterior wall. Its anterior wall measures about 3/4 inch in length while its posterior wall is about 1/2 inch in length. It is the narrowest portion of the urethra. It is surrounded by the sphincter urethrae and is related to the two bulbo-urethral glands, one on each side. It is lined with columnar epithelium.

Development. It develops from the urogenital sinus portion of the cloaca.

Spongy portion of the urethra. The spongy urethra begins from below the perineal membrane as a continuation of the membranous urethra and traverses the bulb, the body and the glans of the corpus spongiosum and ends in the external urethral orifice below the apex of the glans. It is dilated both at its commencement and just above its termination in the external urethral orifice and is known as the *intrabulbar* and *termiral fossa* (navicular fossa) respectively. The terminal fossa is lined with stratified epithelium whereas the rest of it is lined with columnar epithelium.

Development. The penile portion of the urethra, except that within the glans penis, is formed by the fusion of the walls of the urethral or genital groove and anteriorly it opens in the undersurface of the base of the glans penis which is known as the primary meatus. The terminal portion of the urethra (glandal part) develops

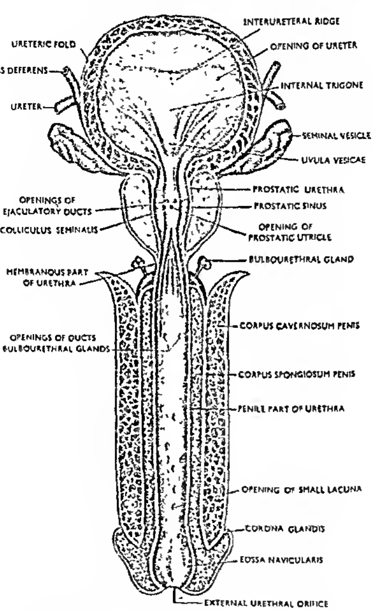


Fig. 761. A coronal section of the urinary bladder together with the prostate and the male urethra and the penis.

from the urethral plate. The urethral plate is formed by the excessive proliferation of the ectodermal cells of the glans which burrow through it and forms a cord of cells which intervenes between the apex of the glans on one side and the primary meatus on the other side. Subsequently this cord is canalised and its posterior margins unite with the margins of the primary meatus and thus the two canals are continuous with each other.

THE EXTERNAL GENITAL ORGANS (MALE)

The penis. The penis, a latin word meaning "a tail" is the male organ of copulation which is a cylindrical body consisting of three fibro-elastic cylinders, the right and the left corpora cavernosa penis, and the corpus spongiosum penis.

Measurements:

Length:		
In flaccid condition	..	8 to 12 cm.
In erect condition	..	12 to 18 cm.
Breadth:		
In flaccid condition	..	3 to 4·5 cm.
In erect condition	..	4 to 5 cm.

Parts for examination. It consists of an attached perineal portion known as the *root*, a free pendulous portion known as the *body*, which ends into a bulbons swelling called the *glans penis*, an anterior or *dorsal surface* and a ventral or *urethral surface*.

The *root of the penis*. The penis has three roots by which it is anchored to the body and are collectively called "the root of the penis". The root of the penis lies in the superficial pouch of the perineum and consists of two bilateral limbs, one on each side, and a median one. Each of the bilateral limbs is attached to the medial aspect of the inferior ramus of the pubis and is known as the *cus penis* while the median limb which forms a conspicuous bulging at its posterior end, is known as the *bulb of the penis* and is firmly attached to the superior surface of the perineal membrane. Thus the bulb of the penis together with the two crura, one on each side, constitutes the formation of the root of the penis.

Crus penis. Each crus penis forms a tapering, fibrous, posterior extremity by means of which it is attached to the medial aspect of the inferior ramus of the pubis. From their narrow tendinous attacbment the two crura gain in bulk, become changed into erectile tissue, and each succeeds to become the corpus covernosum penis. The two corpora convernosa penis converse and fused together anteriorly. Each crus penis is embraced by the ischiocavernosus with which it is fused and thus becomes amply supported.

The bulb of the penis. It is formed by the posterior bulbous extremity of the corpus spongiosum penis and lies within the superficial pouch of the perineum where it is firmly attached to the perineal membrane. About 1 to 1.5 cm. in front of its posterior extremity its superior surface is pierced by the membranous urethra and on either side at its floor it is pierced by the duct of the bulbourethral gland. The bulb of the penis is surrounded by (except its sup. surface) the bulbospongiosus muscle which gains its attachment on it.

The body. The body of the penis is formed mainly by the erectile tissue consisting of two corpora cavernosa penis and the corpus spongiosum penis (corpus cavernosum urethorae). Distally the two corpora cavernosa penis fuse together so as to form a single body with a grooved under-surface but proximally they diverse to form the crura of the penis. The blunt distal extremity of the fused corpora cavernosa penis is capped by the glans penis. The corpus spongiosum penis lies in the groove on the under-surface of the two fused corpora cavernosum and it is expanded distally to form the *glans penis* and proximally to form the *bulb of the penis* which is fixed to the perineal membrane. The corpora spongiosun penis is traversed by the urethra in its whole length.

Each of the three cavernous bodies, (they are called cavernous because, they contain enlarged venous spaces within them) is surrounded by a fibro-elastic membrane known as the *tunica albuginea.* The tunica albuginea for the two corpora cavernopa penis forms a common investment and consists of outer longitudinal and inner circular fibres which send in a septum between the two bodies known as the *septum penis.* The septum penis is of considerable thickness and is a complete

septum close to the root of the penis but towards the other end it is thin and imperfect and sends in a series of processes within from dorsal to the ventral aspect so as to form numerous cleft. The cleft with the fibrous processes resemble the teeth of a comb and hence the septum penis is also called the *septum pectiniforme*. Surrounding all the three bodies is another membranous fascia called the *fascia of the penis* or the deep fascia of the penis. The dorsal surface of the body of the penis is formed the two corpora cavernosum penis while its ventral is formed mainly by the corpus spongiosum and partly the under-surface of the lateral edges of the two corpora cavernosa.

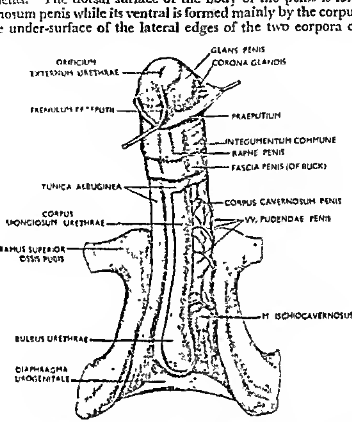


Fig. 762 The coverings of the penis. With kind permission from Lederle Laboratories Ltd Drawn by Mr. Paul Peck.

The glans penis. It is formed by the distal expanded end of the corpus spongiosum penis and is conical in shape. In it there lies the slit-like anterior aperture of the urethra at the margin of which the skin covering the glans is continuous with the mucous membrane of the urethra. It fits in with the distal blunt extremity of the fused corpora cavernosa penis and at the junction of the two is a constriction called the *neck of the penis*. Overhanging the neck, the glans forms a rim-like elevation known as the *corona glandis*.

From the urethral margin the skin fold fuses over glans penis and from the level of the neck it is reflected downwards as a free and after a short course is folded up to become continuous with the general skin covering the penis. This double folds of free skin hooding over the glans is called the *prepuce* or the *fore-skin*. A ridge like triangular fold of skin connects the deep layer of the prepuce with the ventral aspect of the glans penis opposite the median plane and is known as the *frenulum* of the prepuce.

Coverings of the penis. The coverings of the penis are the following:

(1) Skin
(2) Subcutaneous tissue containing the *dartos muscle*.
(3) Fascia of penis or the deep fascia of the penis.
(4) Tunica albugenea for the corpora cavernosa.

(1) The *skin* of the penis is very loose and lax and it is more pigmented and has no hairs. It is continuous with the skin of the abdomen above and with the skin of the scrotum below.

(2) The *subcutaneous tissue is formed by the dartos muscle and is characterised by absence of fats or adipose tissue.* It is continuous with the fascia Camper and Scarpa of the lower abdomen and with the dartos muscle of the scrotum.

(3) *Fascia of penis.* It is the deep fascia of the penis which forms a common membranous sheath for the three cavernous bodies of the penis and lies underneath the dartos muscle from which it is separated by some loose connective tissue. Distally it blends with the skin at the neck of the penis and consequently *it is absent over the glans.* Proximally towards its roots the fascia of the penis receives expansions from the ischiocavernosus and the bulbospongiosus muscles and gives attachment to the suspensory ligament of the penis.

(4) *Tunica albuginea for the corpora cavernosa.* It is a white membranous envelope which intimately surrounds the corpora cavernosa penis in front and the corpora spongiosum penis pesteriorly. The sheath for the corpora cavernosa penis forms a common envelope for the two corpora cavernosa and sends a partition between the two known as the *septum of the penis.* The corpus spongiosum penis has its own separate tunic (tunica albuginea).

Ligaments of the penis. The ligament of the penis are the *fundiform* and the *suspensory ligaments.* The *fundiform ligament* is a band of fibrous tissue which extends from the lower end of linea alba and splits into two lamellae to enclose the penis

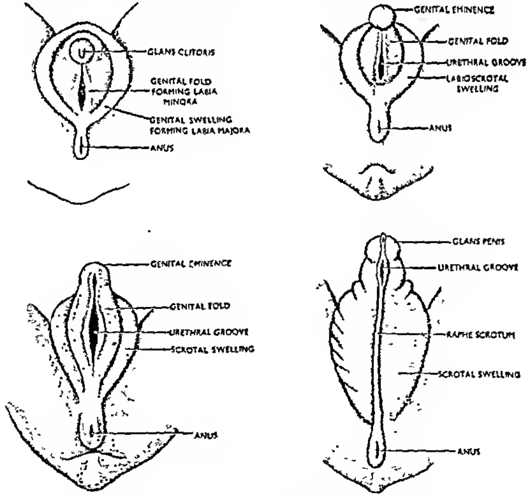


Fig. 763. The development of the male internal genitalia.

and finally ends below by fusing with the scrotal septum. The *suspensory ligament* of the penis is triangular in shape and its base is attached to the condensed mass of fibro-areolar tissue in front of the symphysis pubis and its apex is attached to the fascia of the penis.

Vascular supply. The *arteries supplying the erectile tissue* of the penis are the deep artery of the penis and the artery to the bulb both of which are branches from the internal pudendal artery and are placed beneath the fascia of the penis. The *arteries supplying the skin and the subcutaneous tissue* are the superficial and the deep external pudendal branches of the femoral artery, and the dorsal artery of the penis, branch of internal pudendal artery.

The *veins* draining the penis are the superficial and the deep dorsal veins. The superficial dorsal vein drains the skin and the subcutaneous tissue, lies superficial to the fascia of the penis and ends by opening into the great saphenous vein through the external pudendal veins. The deep dorsal vein after communicating with the internal pudendal vein terminates into the prostatic venous plexus by passing between the anterior margin of the perineal membrane and the interior pubic ligament.

Nerve supply. The vasomotor nerve for the penis is the nervus errigens from the second and the third sacral nerves. The dorsal nerve of the penis supplies the muscular elements of the penis as well as the skin of the penis. The genital branch of the genitofemoral nerve and the terminal twigs from the ilioinguinal nerve supply the skin adjoining the symphysis pubis.

Lymphatics of the penis. The lymphatics draining both the superficial and the deep tissues of the penis except the glans penis terminate in the superficial group of the inguinal lymph nodes (medial members). The lymphatics draining the glans penis accompany the urethra and terminate in the deep group of inguinal lymph nodes and into external iliac lymph nodes.

Structure of the penis. A transverse section of the penis shows its usual coverings namely the skin, subcutaneous tissue containing plain muscle fibres (dartos muscle), deep fascia, tunica albuginea and the structures composing the corpora cavernosa and the spongiosum penis.

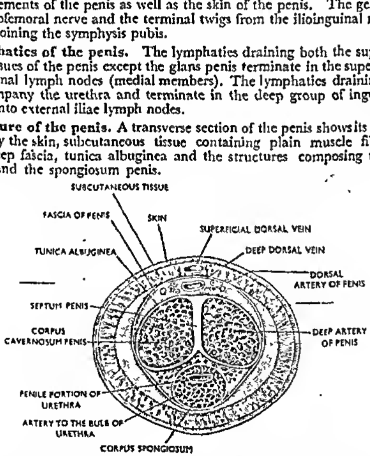
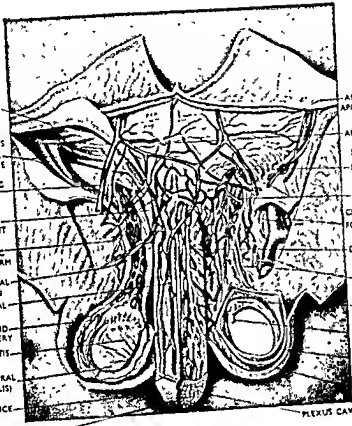


Fig. 764. A transverse section of the penis.

The tunica albuginea sends in innumerable processes or trabeculae within the corpora cavernosa penis which subdivide each body into innumerable spaces which are lined by flattened cells resembling the endothelium. The spaces are filled in with blood and the trabeculae are made up of white fibrous tissues, elastic fibres,



A dissection of the male external genitalia and the reproductive organs. With kind permission from : Lederle Laboratories Ltd. Drawn by Mr. Paul Peck.

[To face page 954]

plain muscle fibres, nerves and innumerable blood vessels. The whole arrangement gives it an appearance of a sponge, in the intertices of which, it contains large blood spaces and hence it is called "cavernous". The corpus spongiosum penis is similarly made up of cavernous tissues but here it is pierced by the urethra and the trabeculae contain more elastic fibres.

Mechanism of erection of the penis. The mechanism of erection of the penis depends on psychological sex feeling and afferent sex stimulation which cause engorgement of the small tortuous arteries (helicine arteries) in the penis. The engorged helicine arteries pour out their contents directly into the cavernous spaces which result in expansion and elongation of the penis. The veins are also engorged and their flow is retarted by the contraction of the ischiocavernosus and by the tough penile fascia compressing on them. The whole mechanism can be compared to a collapsed tube, blunt at one end, into which sufficient amount of fluid is made to run and then it is constricted at its open mouth thereby preventing flowing back of the fluid.

Development. The penis is formed from the excessive growth of the genital tubercle situated at the headward end of the cloacal membrane and from the extension of the genital groove into it. The genital groove invades the ventral aspect of the genital tubercle and both are elongated to form the penis except the glans penis which develops from the urethral plate.

Developmental anomalies

(1) Its *shape* may be altered due to associated anomalies of the urethra such as epispadias, hypospadias, hermaphroditism.
(2) Its *size* may be rudimentary
(3) Its *number* may be double } very
(4) There may be *complete absence* of the penis } rare
(5) The opening of the prepuce may be very small, so that, it cannot be retracted over the glans and there is difficulty in micturition. This condition is known *as phimosis* and is a very common anomaly.

SCROTUM

The scrotum or the rugose pouch of skin and subcuteneous tissue for the testis, is of variable shape and size and hangs down from the lower part of the symphysis pubis. It hangs a little lower on the left side due to lower descent of the testis on the same side. It presents a median ridge known as the *raphe scroti* by which the scrotum can be divisible into two halves. The raphi scroti is continue dbackwards into the perineum and forwards over the urethral surface of the penis.

Identification. When the testes bave been taken out the scrotal skin can be identified by the following peculiarities:

(1) The scrotal skin is thrown out into a series of *transverse ridges* (rougosity) due to the presence of the dartos muscle in its subcutaneous tissue.

(2) The scrotal skin is *more pigmented* and on it there are *long coarse hairs* which are parsely distributed.

(3) The *raphe scroti* forms a median ridge which subdivides the scrotum into two halves.

(4) The skin of the scrotum does not contain any fat.

The coverings of the scrotum or its constituent layers:

(1) Skin. (2) Superficial fascia containing the dartos muscle. This fascia forms an imperfect partition, the scrotal septum. (3) External spermatic fascia derived from the aponeurosis of the external oblique muscle of the abdomen. (4) Cremasteric fascia, a prolongation from the internal oblique muscle. (5) Internal spermatic fascia, a continuation of the transversalis fascia. (6) Parietal layer of the tunica vaginalis derived from the parietal peritoneum.

The parietal layer of the tunica vaginalis together with the other coverings of the scrotum becomes thickened and fused together opposite the bottom of the scrotal sac and is attached to the same (bottom of the scrotal sac) to form the *scrotal ligament.*

The scrotal ligament is believed to be the vestige of the gubernaculum testis and during operation of the hydrocele, a condition in which fluid accumulates in the vaginal sac, the scrotal ligament needs to be divided to isolate the sac.

Artery supply. The arteries supplying the scrotum are the scrotal, artery, the external pudendal branch of the femoral artery and the cremasteric branch of the inferior epigastric artery.

The *veins* are corresponding to the arteries. The cremasteric vein opens into the inferior epigastric vein, the internal pudendal to great saphenous and the scrotal to the internal pudendal vein.

Nerve supply. *Sensory nerves.* The cutaneous nerves for the scrotum are the scrotal branches of the perineal nerve, the genital branch of genitofemoral nerve, the ilioinguinal nerve, and the perineal branch of the posterior femoral cutaneous nerve.

Motor nerves. The dartos muscle is supplied by branches from the hypogastric plexus of sympathetic (plexus that accompanies the vas deferens) and is involuntary in action. The cremasteric muscle is supplied by a branch from the genital branch of the genitofemoral nerve.

Lymphatics. The lymphatics draining the scrotum terminate into the medial members of both the groups of the *superficial inguinal lymph nodes.*

Development. The scrotum develops from the bilateral labio-scrotal folds.

Developmental anomalies. (1) Anomalies of the scrotum may arise as a result of defective obliteration or non-obliteration of the processes vaginalis and these conditions have been dealt with in connection with descent of the testis (see page 992).

(2) *Infantile scrotum.* In some cases due to defective formation of the scrotal cavity the scrotum remains as rudimentary pouch (Infantile scrotum) or the pouch may not develop at all. These conditions are usually associated with undescended testis.

(3) *Bifid Scrotum.* In this condition the two halves of the labio-scrotal folds fail to fuse together in the median plane and a median cleft persists in between the two. Such condition is usually associated with fusion defects of the urethra (hypospadius, hermaphroditism).

THE SEMINAL VESICLES

The seminal vesicles are two sacculated, pyramidal pouches, one on each side, situated between the base of the urinary bladder in front and the rectum behind. It is obliquely placed being directed downwards, medially and forwards and runs parallel to the terminal part of the vas deferens lying on its medial side.

Measurement:

Length—2 inches
Breadth—¾ inch (across its widest part)
The uncoiled tube, of which it is a coiled sac, measures about 10-12 cm. in length and 3-4 mm. in diameter.

Sheath. Each seminal vesicle is surrounded by a dense fibrous sheath derived from the visceral layer of the pelvic fascia.

Parts for examination. It consists of a broad upper end or pole, a narrower lower end or pole, an anterior and a posterior surface, medial and lateral borders and a duct.

The *upper pole* is broad and rounded and is directed upwards, backwards and laterally and is related to the vas deferens and the ureter.

The *lower pole* is narrow and is directed downwards, medially and forwards and is succeeded by its duct. The duct from both the sides converge together with the vas deferens intervening. The duct joins with the vas deferens at an acute angle to form the ejaculatory duct.

Anterior surface. The anterior surface is intimately related to the base of the bladder between the ureter and the prostate.

Posterior surface. The *upper part of the posterior surface is covered by the peritoneum of the greater sac.* Its lower part is uncovered by the peritoneum and is related to the rectum from which it is separated by the rectovesical fascia (fascia of Denonvillier).

Lateral border. It is intimately related to the prostatic venous plexus. Its *medial border* is related to the ampulla of the vas deferens.

Vascular supply. The arteries supplying the vas deferens are the branches from the inferior vesical, middle rectal and artery to the vas deferens. The veins are corresponding to the arteries.

Lymphatics. The lymphatics draining the seminal vesicles terminate in the internal iliac group of lymph nodes.

Nerve supply. Nerves are derived from the pelvic plexus.

Functions. They behave like secreting glands and add their content to the seminal fluid during sexual act.

Development. During the fourth month each seminal vesicle arises as outpouching of the lower end of the mesonephric duct immediately above the prostatic buds.

Structure of seminal vesicles. It consists of an outer fibrous coat derived from the plelvic fascia, an inner mucous coat and an intermediate muscular coat. The muscular coat consists of outer longitudinal and inner circular fibres. The mucous coat is lined by columnar epithelium and is characterised by the formation of innumerable diverticula.

Age-changes. Before puberty the muscular and connective tissue components of seminal vesicles become more developed than its mucous membrane which is comparatively smoother due to scanty folds. At puberty the mucous membrane becomes highly developed and is thrown into innumerable folds by the influence of the male hormone. At old age it involutes either partially or completely due to deficiency of sufficient androgen.

Ejaculatory ducts. The ejaculatory ducts are two in number, one on each side of the median plane and each is formed by the union of the excretory duct of the seminal vesicle and the terminal portion of the vas deferens. Each duct measures about 2 cm. in length. The two ducts pierce through the base of the prostate and are directed downwards and forwards and slightly medialwards so that finally they converge to each other and end by opening into the prostatic part of the urethra on either side of the prostatic utricle at a little lower level than the latter. At its commencement each duct measures about 2 mm. in diameter but in its course it gradually narrows down and finally at its termination it is represented by a pin-point opening.

Structure of the ejaculatory duct. The portion that pierces the prostate gland has no outer fibrous layer otherwise it has the same layers as the seminal vesicles but here the outer muscular layer is formed by circular fibres whereas the inner muscular is formed by the longitudinal fibres.

THE SPERMATIC CORD

It is a crod-like structure by which the testis is suspended into its scrotal sac. It is called spermatic cord because one of its constituents is a duct, the vas deferens, which carries spermatozoa from the testis to the seminal vesicle and the prostatic part of the male urethra.

Extent. The spermatic cord extends from the upper part of the posterior border of the testis to the deep inguinal ring beyond which the constituents of the spermatic

cord run in various directions in the extraperitoneal tissue and loses its cord-like character.

During foetal life the testis in its course of descent from the abdominal cavity into the scrotal sac carries its duct, the vas deferens, together with its blood vessels and nerves and all these structures meet together at the deep inguinal ring so as to form a cord-like structure, the spermatic cord. It then traverses through the inguinal canal, comes out of it through the superficial inguinal ring and then descends into the scrotal sac and terminates into the upper part of the posterior border of the testis.

Thus the spermatic cord has a *scrotal course* and an *inguinal course*. In its scrotal course it ascends vertically upwards to the front of the pubic crest where it can be rolled as a cord-like structure under the palpating finger. In its inguinal course it runs almost horizontally lateralwards through the inguinal canal.

Coverings of the spermatic cord. The coverings of the spermatic cord are following from within outwards:

(1) *Internal spermatic fascia.* Derived from the transversalis fascia as it passes through the deep inguinal ring.

(2) *Cremasteric fascia.* Derived from the cremaster muscle as it passes through the medial part of the inguinal canal.

(3) *External spermatic fascia.* A thin loose fascia which is derived from the margins of the superficial inguinal ring.

Thus the scrotal part of the spermatic cord lying outside the inguinal canal acquire three coverings, internal spermatic fascia, cremasteric muscle and fascia and the external spermatic fascia from within outwards; in the medial half of the inguinal canal from the lower border of the internal oblique muscle to the subcutaneous inguinal ring it has two coverings, internal spermatic fascia and the cremasteric muscle and fascia and in the rest of its extent in the inguinal canal it has only one covering, the internal spermatic fascia.

Content of the spermatic cord:

(1) Vas deferens.
(2) Testicular artery—a branch of abdominal aorta.
(3) Pampiniform plexus.
(4) Artery to the vas deferens—a branch of superior vesical.
(5) Cremasteric artery—a branch of inferior epigastric.
(6) Testicular lymphatics—terminates into internal iliac and aortic lymph nodes.
(7) Genital branch of genitofemoral nerve.
(8) Testicular plexus of sympathetics—from aortic and renal plexuses.
(9) Branches from the hypogastric plexus of nerves that accompany the vas deferens.
(10) Remains of the processus vaginalis.
(11) Ilioinguinal nerve—it is associated with the spermatic cord in its course from the medial half of the inguinal canal to the scrotum.

Relative position of the constituents of the spermatic cord. The vas deferens forms the posterior most structure. The artery to vas deferens accompanies it and is incorporated within its sheath. The branches from the hypogastric plexus of sympathetic nerves also accompany the vas deferens. The remains of the tunica vaginalis lies in front of the vas deferens. The testicular artery together with the testicular plexus of sympathetic nerves derived from the aortic and renal plexuses lies in front of the vas deferens and the remains of the tunica vaginalis being embedded within the pampiniform plexus of veins. The pampiniform plexus of veins almost surrounds the vas deferens and forms a close networks of veins which is divisible surgically into *anterior* or *spermatic group* which is closely associated with the testicular artery and a *posterior* or *deferent group* which is intimately associated with the vas deferens (diagram no 765). The pampiniform plexus of veins run together to form

three or four veins at the superficial inguinal ring, they further unite to form two veins at the deep inguinal ring and in the abdomen they unite together to form a single vein, the testicular vein which terminates into the inferior vena cava on the right side and into the left renal vein on the left side.

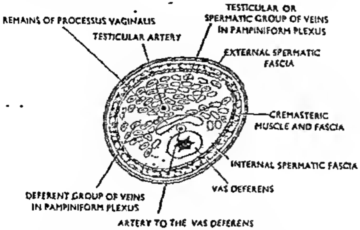


Fig. 765. *A transverse section of the spermatic cord.*

Surgical importance. The pampiniform plexus of veins may be the frequent seat of varicocele in which the cord may be enormously distended. In an operation for such a condition the spermatic group of veins is removed surgically. Encysted hydrocele of the cord is a congenital disease affecting the cord in which fluid accumulates in the processus vaginalis which remains patent between the deep inguinal ring and the tunica vaginalis testis.

PROSTATE

The prostate is a fibro-musculo-glandular organ surrounding the pelvic part of the urethral canal and resembles a chestnut in appearance. Its muscular coat is continuous with the longitudinal muscle fibres of the urinary bladder.

Situation: It is situated within the pelvic cavity behind the lower part of the symphysis pubis and in front of the rectal ampulla.

Measurements and weights:

Vertical	$1\frac{1}{4}$ inches.
Transverse	$1\frac{1}{2}$ inches.
Antero-posterior	$\frac{3}{4}$ inch.
Weight	$\frac{1}{3}$ to $\frac{3}{4}$ oz.

Capsules: The prostate is surrounded by two capsules—true and false. The *true capsule* is formed by a condensed mass of fibroareolar tissue that intimately surrounds the gland and is easily separable from it. The *false capsule* is formed by the visceral layer of the pelvic fascia which lies superficial to the true capsule and provides a sheath common to it and the urinary bladder. The prostatic venous plexus lies between the two capsules and receives in front the deep dorsal veins of the penis. This venous plexus is absent posteriorly. The posterior part of the prostatic capsule is broad, strong and membranous—the *recto-vesical fascia* and is often called by the surgeon, the fascia of Denonvilliers.

The false capsule derived from the pelvic fascia is continuous with the superior layer of the urogenital diaphragm inferiorly and thereby gaining its attachment to the pubic arch through the latter. The median puboprostatic ligament connects

the anterolateral part of the capsule to the back of the lower part of the body of the pubis whereas the lateral puboprostatic ligament connects it with the fascia of the levatores ani posterolaterally and thus the prostate is sufficiently secured in position.

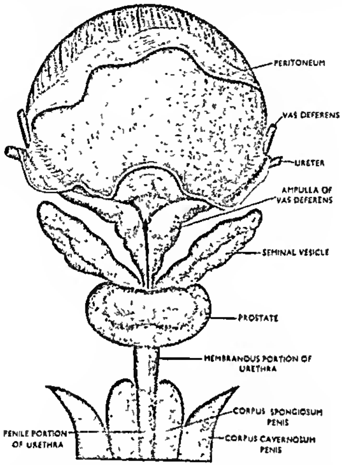


Fig. 766 The urinary bladder together with the prostate and seminal vesicles.

Parts for examination: *Anatomically* it consists of a base or superior surface, an apex and an anterior, a posterior and two inferolateral surfaces and two lateral lobes and a median lobe.

Base or superior surface: The base is directed upwards and is continuous with the neck of the bladder. It is pierced by the urethra, which lies anteriorly opposite the median plane, and by the ejeculatory ducts which lie posteriorly on either side of the median plane. It is in relation to the terminal part of the vas deferens and the seminal vesicles.

Apex: The apex is directed downwards and is in contact with the superior layer of the urogenital diaphragm and is continuous with the membranous portion of the urethra.

Anterior surface: The anterior surface lies behind the symphysis pubis from which it is separated by the retropubic pad of fat and the pudendal plexus of veins and is connected with the back of the symphysis pubis by the median puboprostatic ligament. It lies at a distance of ¾ inch behind the lower part of the symphysis pubis.

Posterior surface. The posterior surface is related to the rectal ampulla and lies at a distance of 1½ inches from the anus. It can be felt through the rectum by digital examination.

Inferolateral surfaces. The two inferolateral surfaces, one on either side, are embraced by the anterior fibres of the levator ani muscle which act as elevator of the prostate gland and are known as the levator prostatae.

Fissures and lobes. *Anatomically* a vertical median groove on the posterior surface subdivides the gland into *two lateral lobes* which are united together anteriorly in front of the urethra by a fibro-muscular band known as the *isthmus.* Superiorly the base presents an annular groove which intervenes between it and the neck of the bladder and its posterior part is pierced by two ejaculatory ducts and the portion of the gland between them and the urethra is called the *median lobe* of the prostate.

Developmentally: 5 lobes and 5 surfaces.

(1) *Anterior lobe.* It develops in the third month of foetal life from tubules growing from the anterior wall of the prostatic urethra. This lobe completely disappears at 6th year and is represented by the anterior commissure only. It has no glandular tissue and is made up of fibro-muscular tissue.

(2) *Median lobe.* It lies behind the urethra and in front of ejaculatory ducts. Structurally it consists of glandular tissue mostly and hence adenomatous growth is common in this part.

(3) *Posterior lobe.* It lies behind the median lobe (Primary carcinoma common).

(4) *Two lateral lobes.* They are situated at the sides, one on each side, and are joined together in front of the urethra by isthmus which is devoid of glandular tissue.

Surfaces:

(1) Superior surface or base.
(2) Posterior surface.
(3) Anterior surface.
(4) Two inferolateral surfaces.

Structure. It consists of muscular, glandular and fibrous tissues and the proportion is ½ glandular, ¼ muscular and ¼ fibrous. The glandular tissue is arranged in three concentric layers around the urethra and from within outwards they are the inner or mucous, intermediate or submucous and outer layers. The *mucous glands* are simple type of glands and lie just beneath the mucous membrane of the gland. Their ducts open into the prostatic sinus above the level of the colliculus seminalis. The *sub-mucous glands* open into the sinus opposite the level of the colliculus. The *outermost layer of glands* is a branching type of gland and extends to all sides except anteriorly where the two margins of the prostate gland are joined together by a fibromuscular isthmus.

Vascular supply. The **arteries** supplying the prostate are derived from the internal pudendal, inferior vesical and the middle rectal arteries and the vesical branches of the inferior gluteal (all are branches from the anterior division of the internal iliac artery) artery.

The **veins** from the prostate open into the prostatic venous plexus which communicates in front with the deep dorsal vein of the penis and behind with the vesical venous plexus and finally drain the blood into the internal iliac vein.

Nerve supply. It is supplied by pelvic plexus of sympathetics.

Lymphatics. The lymph vessels from the prostate mostly follow the inferior vesical arteries and terminate into the anterior and lateral vesical and into the internal iliac group of lymph nodes; some lymph vessels follow the vas deferens to terminate

into the external iliac group of lymph nodes while a few others run backwards to end into the sacral group of lymph nodes.

Development. During the third month of intrauterine life the glandular part of the prostate develops as a series of solid outgrowths from the epithelium of the urogenital sinus. Later on, all these solid outgrowths fuse together to form a tubular mass from which the glandular part of the prostate is derived. The muscular part of the organ develops from the surrounding mesoderm during the fourth month of intrauterine life and fuse with the glandular part.

N.B.—The so called anterior lobe of the prostate is often referred to but in normal adult person it never exists (Buchanon) and it is only present during early embryonic life. During the third month of foetal life it is formed from the tubules growing from the anterior part of the prostatic urethra. These tubular growths, which form the anterior lobe during early foetal life (third month) begins to disappear from the 22nd week of embryonic life and before sixth year of life it completely disappears and its place is taken up by the fibromuscular isthmus of the gland. Thus we see that the adult prostate consists of 2 lateral lobes and a median lobe, whereas the foetal prostate and the prostate of early childhood (before 6 years), consist of two lateral lobes, a median lobe, a posterior lobe, and an anterior lobe. The fascia of Denonvillers is the fibrous remains of two fused peritoneal layers, which in foetal life separates the prostate and the rectum.

Applied anatomy. The prostate gland is the frequent seat of malignant disease (cancer). Hypertrophy of the gland is a usual phenomenon during advanced life and as all hypertrophy affects the mucous glands (young) the line of least resistance is towards the interior of the bladder and the urethral canal and consequently the hypertrophied gland projects into the bladder through the internal urethral orifice causing obstruction in the flow of urine. Hypertrophy of the lateral lobes is not uncommon.

An approach to the prostate from the perineum. Give a transverse incision in front of the anus opposite the ischial tuberosities. Retract the skin and the fascia both upwards and downwards and expose the sphincter ani externus. Cut through the fibres of the sphincter ani externus and separate it from the central tendon of the perineum. Then pull the anal canal backwards and separate the urogenital triangle from the anal triangle. Then with the aid of the handle of the knife separate the anal canal from the perineal membrane and pull it further backwards. The anterior margins of the levator ani are now exposed. Then with the help of the finger push the pelvic fascia stretching between the rectum and the prostate upwards and now the posterior aspect of the prostate and the anterior aspect of the rectum are exposed.

THE FEMALE EXTERNAL GENITAL ORGANS

The female perineum, like that of the male, is subdivided into urogenital triangle and the anal triangle. The anal triangle bears the same features as that in the male while the urogenital triangle, *although it maintains many features in common,* bears the external genital organ which requires separate descriptions.

The *labium majus* represents the male scrotum and splits into two labia majora in the female. These are elongated skin folds situated on either side of a median cleft, the *pudendal cleft.* Both anteriorly and posteriorly they unite together to form the anterior and posterior commissures respectively. Above the anterior commissure and opposite the anterior aspect of the symphysis pubis they are continuous with each other and form an elevated mount of fat known as the *mons pubis.*

The *labia minora* are skin-folds situated on the medial side of the labia majora within the pudendal cleft. The upper end of each labia minora splits into two folds which are continuous with the fellow of the opposite side in the median plane. The upper fold covers the glans clitoris and corresponds to the prepuce in the male while the lower fold is attached to the undersurface of the glans clitoris to form its frenulum.

The *vestibule of the vagina* lies in between the two labia minora and is triangular in shape. The vaginal opening is situated in the lower part of the vestibule and

situated above and in front of the vaginal opening is the slit-like opening of the urethra. A thin irregular fold covers the mouth of the vagina known as the hymen in the vergin.

The *clitoris* or the *female penis* is situated at the apex of the vestibule and has two crura, a prepuce and a frenulum.

The *bulb of the vestibule* is the soft structure that lies between the vagina and the glans clitoris and corresponds to the bulb of the penis. It is a bilateral structure in the female which surrounds the urethra and the vagina.

The *greater vestibular gland or Bartholin's gland* corresponds to the bulbo-urethral gland in the male but *it has a different situation in the female.* It lies against the lateral wall of the lower part of the vagina and its duct which measures about ¾ inch in length, opens into the vagina in the angle between the attached border of the hymen and the posterior end of the labia minora.

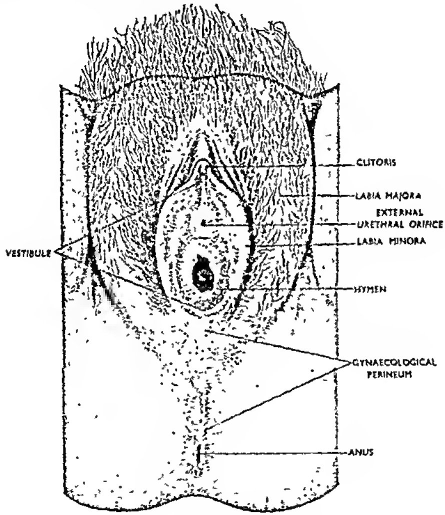


Fig. 767. The female external genitalia.

The *vagina*, a latin word meaning a "sheath" is the female organ of copulation and resembles a tube whose walls are opposed to each other. The axis of the tube runs parallel to the plane of the inlet of the pelvis. It consists of anterior and posterior walls. Its *anterior wall* is shorter than its posterior wall and measures three inches in length while its posterior wall measures about four inches in length. It extends from the pudendal cleft to the lower end of the recto-uterine pouch. The

of its anterior wall is pierced by the cervix uteri, its middle-third is in contact with the base of the urinary bladder and the urethra while its lower-third lies in the lower part of the vestibule and is lined by the same mucous membrane that lines the urethra. Its *posterior wall* in its upper-fourth is covered by the peritoneum and is separated from the rectum by the recto-uterine pouch. Its middle two-fourths are separated from the rectum by some loose areolar tissue while its lower one-fourth is separated from the anal canal by the perineal body. In its course, the vagina pierces the centre of the perineal membrane. On either side it is embraced by the anterior fibres of the levator ani and the bulb of the vestibule. Surrounding the attachment of the cervix uteri is a gutter and according to the situation it is named as anterior, posterior and lateral *fornices*. Superiorly each lateral forix is crossed by the base of the broad ligament, the ureter and the uterine artery.

Artery and nerve supply. The arteries supplying the vagina are the vaginal, uterine, and middle rectal arteries from the internal iliac artery and the veins drain into the internal iliac vein.

The nerves supplying the vagina are the vaginal plexus of nerves and the nervus errigens.

Structure of the vagina. It consists of a mucous coat lined by stratified sqamous epithelium. In the lower part of the vagina the mucous membrane forms the rugae and papillae while in the deepest part it is smooth. Surrounding the mucous coat is a layer of muscular coat consisting of circular and longitudinal fibres and outside the muscular coat is a fibroareolar adventitous coat.

Female urethra. The female urethra is one and a half inches long and begins from the internal urethral orifice and then curves downwards and forwards below the symphasis pubis and lies in front of the anterior wall of the vagina and finally it pierces the perineal membrane and ends in the external urethral orifice situated in the vestibule about one inch below the clitoris.

FEMALE REPRODUCTIVE ORGANS

THE UTERUS

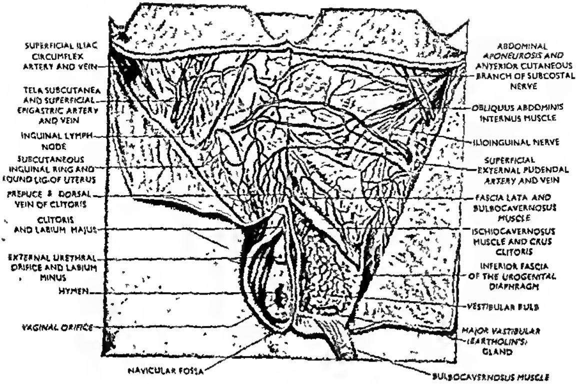
The uterus is a pyriform hollow muscular organ of the female genital tract contained within the pelvic cavity and is situated in between the urinary bladder in front and the rectum behind. It communicates with the vagina in front and with the general peritoneal cavity by uterine tube which opens into its lateral angle.

Different parts. It consists of a fundus, a body and the cervix. The fundus of the uterus forms the upper expanded portion of the uterus and lies above a line joining the two uterine tubes. The body of the uterus gradually diminishes in size from the fundus to a constriction below known as the isthmus which corresponds internally to the internal os. The cervix uteri extends from the level of the internal os to the external os and is divisible into supravaginal and vaginal portions by the attachment of the vagina.

Measurements and weight:

Body and fundus	2 inches.
Cervix uteri	1 inch.
Uterine cavity and cervical canal	$2\frac{1}{2}$ inches.
Weight	1 to $1\frac{1}{2}$ oz.

Peritoneal relation. Body and fundus—are completely covered by peritoneum. Cervix uteri—The supravaginal portion of the cervix uteri is covered by peritoneum only in its posterior aspect, it is not covered by peritoneum anteriorly.



A dissection of the female external genitalia. With kind permission from: Lederle Laboratories Ltd. Drawn by Mr. Paul Peck.

[To face page 964]

Axes of the uterus. The long axis of the body meets the long axis of the cervix at an angle which is open forwards and this position of the uterus with a forward concavity is known as the *anteflexed position.* The long axis of the cervix meets the long axis of the vagina at an angle which is open anteriorly and the whole uterus is turned forwards on the vagina and this position of the uterus is known as the *anteverted position.*

Fundus. The fundus of the uterus lies above the line joining the two uterine tubes. It is convex in all directions and is continuous with the anterior and posterior surfaces. It is completely covered by the peritoneum and is related with some coils of the small intestine.

Body. The body is continuous above with the fundus and below with the cervix at the level of the internal os which is a constriction at the junction of the body and the cervix and corresponds to the internal os internally. It gradually tapers towards the cervix. It consists of vesical or anterior and intestinal or posterior surfaces and two lateral margins, right and left.

The *vesical* or *anterior surface* is flat and is directed downwards and forwards. It lies in contact with the urinary bladder which lies below and in front of it. It is covered by peritoneum as far as the level of the internal os from where it is reflected on to the superior surface of the urinary bladder forming the utero-vesical fold and the excavation between them (bladder and uterus) is known as the *vesico-uterine pouch.*

The *intestinal* or the *posterior surface* is convex and is directed upwards and backwards. It is covered by peritoneum. Traced downwards and backwards the peritoneum is seen to cover the supravaginal portion of the cervix uteri and the upper part of the posterior wall of the vagina and then is reflected to the rectum forming the recto-uterine fold. The peritoneal excavation in this situation between the uterus and the rectum is known as the *recto-uterine pouch* (*pouch of Douglas*).

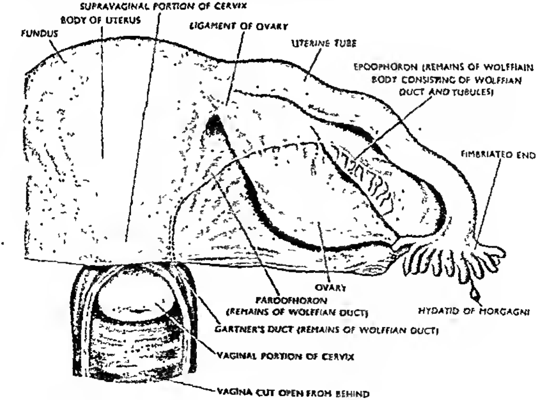


Fig. 768. The uterus with the broad ligament and a part of the vagina. (Seen from behind.

The intestinal surface of the uterus is related to the rectum, sigmoid colon and some coils of the small intestine.

The *lateral margin* of the uterus is convex and gives attachment to the broad ligament which stretches laterally to the pelvic wall. It is related to the uterine vessels which lie in between the two layers of the broad ligament. The uterine tube pierces the uterus at the upper end of each lateral margin. Lying below and in front of the tube is the round ligament of the uterus, and below and behind is the ligament of the ovary.

Cervix uteri. The portion of the uterus from the level of the internal os to the external os forms the cervix uteri. It is about 2·5 cm. in length and is more cylindrical in form than the body. It projects through the anterior wall of the vagina and protrudes into the cavity of the same. Thus it is divided into an upper supravaginal portion and a lower vaginal portion.

The *supravaginal portion of the cervix uteri* is covered by peritoneum posteriorly but it is devoid of peritoneum anteriorly. It is related in front to the bladder from which it is separated by some loose areolar tissue known as the *parametrium*. Posteriorly it is in relation to the rectum and the recto-uterine pouch which contains a few coils of the ileum and sometimes the pelvic colon. On either side, the cervix uteri is in relation to the uterine artery and ureter. The ureter and the uterine artery run side by side for a distance of 2·5 cm., and then the uterine artery crosses in front of the ureter and ascends upwards in between the two layers of the broad ligament. The ureter lies at a distance of 2 cm. from the cervix uteri.

The *vaginal portion of the cervix uteri* projects into the anterior wall of the vagina and lies in between the anterior and posterior vaginal fornices. In the centre of the vaginal portion of the cervix there is an oval depression leading into a circular aperture known as the *external* os which is bounded by two lips, anterior and posterior. The anterior lip is shorter and thickened and projects to a lower level than the posterior lip. Through the external os the uterine cavity communicates with the vagina.

In a horizootal section through the uterus the cervix is found to contain a canal within—the *cervical canal* which is fusiform in appearance and communicates above with the cavity of the uterus through a constricted opening known as *internal os* and below with the vagina through the external os. The wall of the canal presents an anterior and a posterior longitudinal ridge and from each of these ridges a series of small mucous folds spread in the walls of the canal. These folds are known as *palmate folds* and the longitudinal ridges with these folds, which resemble the appearance of branches from the stem of a tree, are known as *arbor vitæ uteri*.

Isthmus. The upper third or less of the cervix is called the isthmus.

Anteriorly the peritoneum is reflected from the level of the internal os to the urinary bladder whereas posteriorly it is covered by peritoneum. The isthmus persents some special features both structurally as well as functionally. The lining epithelium is thinner than that in the body and it contains a fewer glands which are not branched. It is covered by columnar ciliated epithelium. Functionally its mucous membrane undergoes cyclical changes associated with the menstruation but they are less pronounced. During pregnancy, during the first month, it is not affected by any change but during second month it is gradually taken up by the body to form the *lower uterine segment*. In the lower uterine segment the foetal membranes are not attached whereas they are firmly adherent with the lining mucous membrane of the body of the uterus.

Supports of the uterus. The supports of the uterus may conveniently be divided into true and false supports and they have been grouped as follows:

True supports:

1. The muscular sling of the uterus derived from the pelvic diaphragm (levator ani).
2. The condensation of the pelvic fascia around the blood vessels of the organ.

3. Fibromuscular ligaments. In addition to the fibrous tissue they contain muscle fibres which are continuous with the musculature of the uterus. They hypertrophy during pregnancy and involute at the termination of the same.
   (a) Pubo-cervical ligament. PCL
   (b) Ligamentum transversale coli (Mackenrodts ligament) or the lateral cervical ligaments.
   (c) Uterosacral ligaments.
   (d) The round ligament of the uterus. It is not yet definite whether it is a true or a false support. (?)

False supports. The peritoneal connections of the uterus are considered as different *peritoneal ligaments* but as they fail to give effective support (having no firm attachment) they are considered as false ligaments. They have been grouped as follows:

4. Broad ligaments.
5. Anterior ligament of the uterus.
6. Posterior ligament of the uterus.

1. *The muscular sling of the uterus.* It is formed by the pubo-coccygeus part of the levator ani of the pelvic diaphragm. The fibres of pubo-coccygeus part of the levator ani, as they descend downwards, backwards and medially, they pass by the sides of the vagina to gain its posterior aspect and the perineal body in between the vagina and the rectum. In their course they are inserted into the sides and posterior aspect of the vagina and into the perineal body and thus these fibres act as a supporting sling as well as a spincter for the vagina. As the vagina is in direct continuity with the uterus the pubo-coccygeus is also acting as a sling for the latter.

2. *Condensation of the pelvic fascia around the blood vessels of the organ.* They form effective support for the uterus.

(a). *Pubo-cervical ligament.* It extends from the anterior aspect of the cervix uteri to the back of the body of the pubis. It corresponds to the lateral and medial pubo-prostatic ligaments of the male.

(b). *Ligamentum transversale coli* (Mackenrodts ligament) or the *lateral cervical ligaments.* It forms a pair of condensed fibro-muscular bands, one on each side, that extends from the side of the cervix uteri and the upper part of the vagina to the side wall of the pelvis.

(c). *Uterosacral ligaments.* They form two fibro-muscular bands which extend backwards from the posterior aspect of the cervix uteri and then passing on each side of the rectum are attached to the front of the sacrum. They form two bands which embrace the sides of the rectum like the blades of a forcep.

3. *Round ligament of the uterus.* The round ligament of the uterus is a fibro-muscular cord about five to six inches long and extends from the lateral angle of the uterus to the labium majus. At its commencement it is placed below and in front of the uterine tube. In its course it crosses the obturator vessles and nerves, obliterated umbilical artery and external iliac vessels. Then it winds round the inferior epigastric artery, enters the deep inguinal ring, traverses the inguinal canal and is finally lost in the labium majus in front of the symphysis pubis.

It is one of the supports of the uterus and maintains the anteverted and anteflexed position of the uterus and represents the distal portion of the gubernaculum ovary.

4. *Board ligaments.* From each side of the uterus a double fold of peritoneum extends to the lateral wall of the pelvis forming what is known as the broad or lateral ligament of the uterus. The uterus together with the two broad ligaments form a transverse partition in the pelvic cavity and divides it into anterior and posterior compartments.

Each broad ligament consists of anterior and posterior surfaces and superior, inferior, medial and lateral borders. The *superior border* forms a free border along which there runs the uterine tube. The *inferior border* is attached to the anterior wall whereas its lateral border is attached to the lateral wall of the pelvic cavity. Medially it is attached to the side of the fundus, body and supravaginal portion of the cervix. The peritoneum is derived from the peritoneum of the greater sac which is reflected to the uterus from the rectum forming the *recto-uterine fold* and the recto-uterine pouch or the pouch of Douglus and then is reflected into the bladder forming the utero-vesical fold and pouch. The layers of the peritoneum that cover the surfaces of the uterus are spread to the lateral wall of the pelvis as two broad or lateral ligaments of the uterus.

Contents:

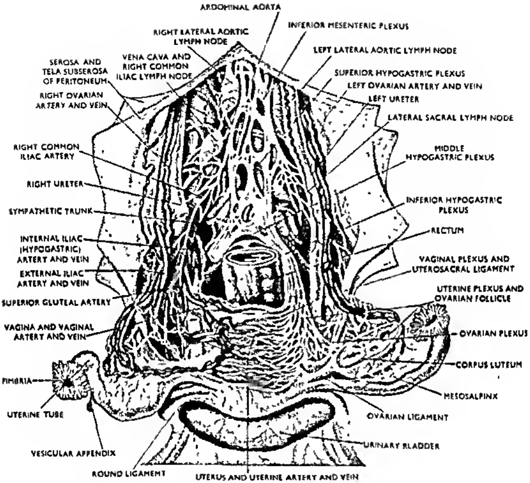
(1) *Part of uterine tube.* It lies along its superior border.
(2) *Part of round ligament of the uterus.* It lies below and in front of the uterine tube.
(3) *Ligament of the ovary.* It lies below and behind the uterine tube.
(4) *Uterine vessels, nerves and lymphatics.* They run along the side wall of the uterus.
(5) *Ovarian vessels, nerves and lymphatics.* They enter the hilum of the ovary through the infundibulo-pelvic ligament.
(6) Paroophorons (Paroo=by the side; Phoron=egg basket or ovary). This is the remains of the mesonephric duct and lies in between the ovary and the uterus.
(7) Epoophoron (Epoo=above; phoron=egg basket or ovary). This is the remains of the mesonephric body containing both tubules and the duct of embryonic life and lies above the meso-ovarian border of the ovary.
(8) Accessory suprarenal gland (sometimes).
(9) Parametrium consisting of unstriped muscle fibres and areolar tissue and fat.
(10) Portion of ureter that crosses the base of the broad ligament. (Text book of Anatomy, Cuningham, and Surgical Anatomy by C. Latimer Callander).

5. *Anterior ligament of the uterus.* This is a peritoneal ligament which extends from the isthmus of the uterus to the base of the bladder (utero-vesical fold of peritoneum).

6. *Posterior ligament of the uterus.* It is formed by that fold of peritoneum which extends from the rectum to the supravaginal portion of the cervix uteri forming the recto-uterine fold of peritoneum and the space contained between the reflections is known as the recto-uterine pouch or pouch of Douglas and is about 1½ inches deep.

Artery supply. The arteries supplying the uterus are the uterine branch of the internal iliac artery and the ovarian branch of the abdominal aorta. As soon as the uterine artery reaches the uterus it becomes extremely tortuous and at the point where the uterine artery meet the cervix uteri it anastomoses with the vaginal branch of the internal iliac artery which also supplies some twigs to the cervical region of the uterus. The tortuosity of the uterine artery is due to the change in size and position of the uterus during pregnancy and different phases of the reproductive period.

The uterine artery reaches a point about 2 cm. lateral to the supravaginal portion of the cervix uteri and crosses above the ureter in this situation and then ascends upwards along the lateral margin of the uterus in between the two layers of the broad ligament to the upper lateral angle of the uterus where it ends by anastomosing with the uterine branch of the ovarian artery. From opposite the lateral margin of the uterus some large branches of the uterine artery penetrate into the myometrium while others pass transversely at a varying depth from its surface and anastomose with similar branches from the opposite side to form arterial arcades. From these arterial arcades numerous branches



A dissection to show the vascular, lymphatic and nerve supply of the female reproductive organs. With kind permission from: Lederle Laboratories Ltd Drawn by Mr Paul Peck. [To face page 969]

penetrate into the myometrium. From the myometrium minute branches run into the endometrium. The endometrial vessels are divided into two types, *short straight vessels* and *long spiral vessels*. The former terminate into capillaries into the basal layer of the endometrium while the latter take a spiral course in between the endometrial glands into the stratum compactum of the endometrium where they end into capillary bed. Structurally the short, straight arteries are characterised by the absence of elastic tissue in their intimal layer.

The *veins* of the uterus form a plexus known as the uterine plexus. The lower part of this plexus is drained by two uterine veins which open into the internal iliac vein while its upper part drains into the ovarian plexus. The uterine plexus communicates below with the vaginal plexus.

Nerve supply. It is only supplied by the sympathetic nerves and derives its fibres from 10th, 11th, 12th dorsal, and 1st lumbar segments; 3rd and 4th sacral segments of the spinal cord are also believed to supply parasympathetic fibres to the uterus.

Lymphatics of the uterus. The lymphatics of the uterus consist of two sets of lymph vessels—(*a*) superficial and (*b*) deep. The deep set of lymph vessels lies within the musculature of the uterus while the superficial set lies just beneath the peritoneum. The collecting vessels from different parts of the uterus pass in the following ways:—

Cervix uteri. The lymph vessels of cervix uteri pass in three directions—(*a*) some pass laterally through the parametrium to end into the external iliac group of lymph nodes; (*b*) some pass posterolaterally to end into the internal iliac group of lymph nodes and (*c*) the remaining lymph vessels run posteriorly through the sacrogenital fold to end into the sacral group of lymph nodes.

Body. It is drained by those lymph vessels which are accompanying the ovarian vessels and are ending into the pre-aortic and the lateral aortic group of lymph nodes.

Fundus. The majority of the lymph vessels of the fundus of the uterus are accompanying those from the body and are ending into the pre-aortic and lateral aortic group of lymph nodes; some end into the external iliac lymph nodes and a few from the sides of the attachment of the uterine tube, accompanying the round ligament, end by joining with the superficial group of inguinal lymph nodes.

Development. The uterus develops from the para-mesonephric ducts, the distal ends of which fuse together to form the uterus whereas their proximal ends form the

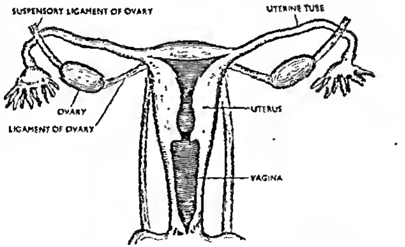


Fig. 769. The ligaments of the ovary and the round ligament of the uterus.

uterine tube. The distal ends of the fused para-mesonephric ducts end in the urogenital cleft from which the external genital parts develop.

Vestigial structures in connection with the uterus and vagina:

(1) *Epoophoron.* It is homologus with the male epididymis and *vas deferens* and is the remains of the Wolffian body.

(2) *Paroophoron.* (duct of epoophoron or duct of Gartner)—Homologus with the male vas deferens and is the remains of the Wolffian duct.
(3) *Hydatid of Morgagni—a Wolffian derivative.* A small cyst hanging by a stalk from the uterine tube at its fimbriated end.
(4) *Skenes duct.* One of the numerous periurethral racemose gland's duct opening in to urethra.

Structures of the uterus. The uterus is composed of serous, sub-serous, muscular and mucous coats. The serous coat is the outermost layer and is derived from the peritoneum and is adherent to the subjacent coat. The *sub-serous layer* is made up of fibrous tissue which is particularly abundant in the region of the cervix and along the lateral margins. The *muscular coat* of the uterus is known as the *myometrium* and forms the main bulk of the uterus. The fibres of the muscular coat interlace each other through which pass the blood vessels and this arrangement explains how the uterine haemorrhage stops when its musculature contracts. The muscular coat is lined interiorly by the mucous coat which is known as the *endometrium*. Structurally the endometrium consists of a stroma of irregular cells with which the endometrial glands are embedded. The cells of the glands are continuous with the cells of the lining epithelium which are of columnar and columnar ciliated types.

The endometrium undergoes a series of changes during each menstrual cycle and in its luteal phase it may be subdivided into three layers, stratum compactum, stratum spongiosum and stratum basale. The stratum compactum consists of a thin layer lining the uterine cavity and is made up of closely packed cells. The stratum spongiosum is the thickest layer next to stratum compactum and consists of loosely arranged cells. The stratum basale lines the myometrium and into it the short straight vessels terminate.

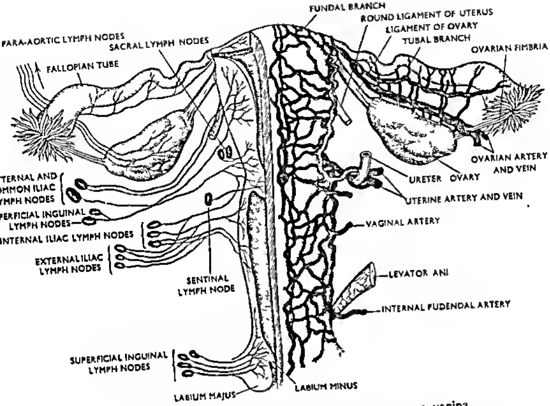
Structurally the cervix is different from the rest of the uterus. It is made up of dense fibrous tissue within which smooth muscle cells are embedded irregularly. To the nacked eye the mucous lining in the cervix is found to form folds and ridges (arbor vitae uteri) whereas in the rest of the uterus it is smooth. In the external os the lining epithelium which is of columnar type, undergoes transition and becomes continuous with the stratified epithelium lining the vaginal portion of the cervix.

The region of the isthmus is structurally similar to that of the body and fundus except that the endometrial glands are less in number, more superficial and they are not branched as are found in the endometrium of the body and fundus.

Cyclical changes in the uterus during the reproductive period. From puberty to menopause (roughly from fifteenth to forty-fifth year) a series of cyclical changes occur in the endometrium which results in the discharge of blood from the uterus at a regular interval of about 28 days and is known as *menstruation*. The menstruation is closely related with the cyclical changes in the ovary brought about by the influence of the anterior lobe of the pituitary gland and may be of two types, "*real menstruation*" and "*anovular menstruation*". In "real menstruation", which is by far the commonest type, there is ovulation of the ovary (Graaffian follicle matures and ruptures to liberate the ovum) and the uterine endometrium is brought under the influence of oestradiol and progesterone and the bleeding occurs in the progestational endometrium. In anovular menstruation (rare) there is no ovulation, however bleeding may occur in the form of menstruation under the influence of oestrogenic hormone and that there is no progestational changes in the endometrium.

Structural changes in the uterine endometrium. The structural changes in the uterine endometrium may better be discussed under two heads, follicular or oestrogenic phase, luteal or progestational phase.

Follicular or oestrogenic phase. This phase begins from the first day of the menstrual bleeding and the uterine endometrium at this stage has been cast off except the stratum basale which contains the stumps of the endometrial glands. Reparation soon starts with proliferation of the cells of the stumps of the endometrial glands under the influence of the oestrogenic hormone. By the end of the fourth or the fifth day



The vascular supply and lymphatic drainage of the uterus, vagina, uterine tube and the ovary.

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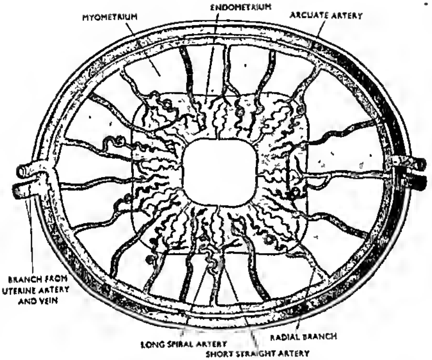

The blood supply of the uterus as seen in a transverse section.

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bleeding stops and by the end of the first week regeneration of epithelium lining the uterine cavity is completed. From the end of the first week till the end of the second week growth activities in the uterine endometrium become a dominent feature in which the endometrial glands enlarge, the coiled blood vessels are formed and dilated and the endometrial stroma becomes oedematous. The sum total of these changes causes the endometrium to be much thicker. At the end of this phase ovulation occurs and the follicular phase changes into the luteal phase.

Luteal or progestational phase. This phase starts from the begining of the third week by the influence of the progesterone of the corpus luteum and is completed towards the end of the fourth week. At this stage changes suffered by the uterine endometrium during the follicular phase are greatly exaggerated; the glands become more tortuous and they acquire secretory activities, the coiled arteries become more tortuous and enlarged, come to lie just under the surface epithelium and they contract and dilate rhythmically. Towards the end of this phase the fluid imbibed by the stroma (oedematous stroma) undergoes resorption and as a result, the endometrium becomes less thick and the blood vessels become compressed to cause stasis. Ultimately this phase terminates with the onset of menstruation by the rupture of the blood vessels.

THE UTERINE TUBES

The uterine or fallopian tubes are the two excretory ducts of the ovary and carries the ova from the ovary to the uterus. 10cm

Each uterine tube is about four and a quarter inches long and quarter of an inch in diameter and is completely covered by the peritoneum of the broad liagment except that portion which is embedded into the substance of the uterus.

Each tube runs at first laterally above the meso-ovarian border of the ovary and then ascends upwards over the tubal extremity of the ovary and finally descends downwards to about against the medial surface of the ovary.

Each tube opens into the lateral angle of the uterus at the junction of the fundus with the body, the orifice being termed the *uterine ostium* through which it communicates with the cavity of the uterus. Its lateral extremity communicates with the general peritoneal cavity by an opening in the posterior layer of the broad ligament known as the *pelvic ostium*.

Different parts. Each tube consists of the following parts:

(1) *Pars uterine tubae.* It is that portion of the tube which is embedded into the substance of the uterus and measures about 1 cm. in length.

(2) *Isthmus.* It is the constricted portion of the tube just succeeding the pars uterine tubae and is very firm and cord-like. It measures from 3 to 4 cm. in length.

(3) *Ampulla.* It just succeeds the isthmus and is the most dilated part of the tube. It measures about ½ the length of the tube (2 inches). As the ampulla is carried laterally it becomes constricted and then widens out in the form of a funnel, the fundibulum.

(4) *Infundibulum.* It is the funnel-shaped expansion of the lateral end of the uterine tube. Its circumferential margin breaks out into a number of fringe-like processes known as the *fimbria.* Due to the presence of these fimbrae it is sometimes called the *fimbriated end.* One of these fimbrae is stout and long and connects the tube with the medial surface of the ovary close to its tubal extremity and is known as the *ovarian fimbria.*

Vascular supply. The arteries supplying the uterine tube are the uterine branch of the internal iliac artery and the ovarian branch of the abdominal aorta. The veins are corresponding to the arteries (uterine and ovarian).

Lymphatics. The lymph vessels drain into pre-aortic and internal iliac group of lymph nodes.

Nerve supply. It is supplied by ovarian plexus of nerve.

THE MAMMARY GLAND OR THE BREAST

In a nulliparous woman the breast or the mammary gland forms the hemispherical elevation on the chest wall consisting of mammary glands and adipose tissue. Each mammary gland is a compound racemose gland resembling modified sweat gland in function and is derived from the mammary ridge of the embryo. Opposite the centre of each breast the wrinkled conical elevation is known as the *nipple* and surrounding the nipple a zone of pigmented area is known as the *areola.* The small nodular elevations in the areola are formed by the underlying sebaceous glands and are known as the *tubercles of Montgomery*. The mammary gland is situated with the superfical fascia and intervenes between the skin and the deep fascia.

Extent of the breast—

Vertical. From second to the sixth rib.
Horizontal. From lateral half of the sternum to the mid-axillary line opposite the fourth costal cartilage.

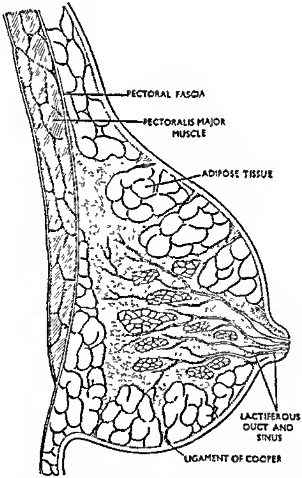


Fig. 770 A view of the anatomical structure of the breast as seen in a vertical section (Diagrammatic).

Bed of the mammary gland or the breast. The deep fascia covering the pectoralis major, serratus anterior, obliquous externus abdominis and the rectus abdominis forms the bed of the mammary gland. Horizontally about ⅔ of it lies over the pectoralis major and about ⅓ over the serratus anterior. Vertically a small

portion of it extends downwards on to the obliquous externus abdominis and the rectus abdominis. Between the deep surface of the gland and its bed (deep fascia) is a collection of loose areolar tissue known as the *retro-mammary tissue* which forms a cushion upon which the organ rests.

Anatomical or Gross structure. Each mammary gland consists of 15 to 20 lobules or glandular units which branch out from the nipple like the spoke of a wheel within the superficial fascia. One of the glandular units, the *axillary tail of Spence*, winds round the lateral margin of the pectoralis major and comes into close relation with the axillary vessels by passing through an opening in the deep fascia, the *foramen of Langer*. Thus the axillary tail of Spence lies deep to the deep fascia while the rest of it lies superficial to the deep fascia. In between the lobules there is a collection of fat and an incomplete fibrous septum derived from the superficial fascia which is connected superficially to the skin and deeply to the deep fascia. This band of fibrous septum that traverses through the interlobular spaces and connects the skin with the deep fascia is known as the *ligament of Cooper or the suspensory ligament of the breast*. Each lobule gives rise to a duct, the *lactiferous duct* which opens into the nipple. Just before its termination each duct forms a fusiform dilatation known as the *ampulla* or *the sinus of the lactiferous duct*. Between the skin and the breast there is a pad of fat except beneath the areola where it consists of a layer of non-striped muscle fibres, a lymphatic and a venous plexus.

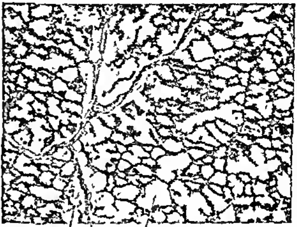


Fig. 771. The histological structure of the mammary gland.

Vascular supply of the breast—

(1) The external mammary branch of the lateral thoracic artery enters the gland from the lateral aspect.

(2) Perforating branches of the internal mammary artery enter the gland from its deep aspect (Those from the second and thrid intercostal spaces are much stouter in case of female).

(3) The second, third and the fourth intercostal arteries, each provides a mammary branch which supplies the gland.

The veins of the mammary gland end by opening into the internal mammary and the axillary veins.

Nerve supply. The breast is supplied by second to the sixth intercostal nerves. The sympathetic nerves supplying the glandular tissue reach it through the second, third and the fourth intercostal nerves.

Lymphatics of the breast. The breast is drained by two sets of lymph vessels—*the lymphatics of the parenchyma of the breast* and *the lymphatics of the skin over the breast.*

(1) **Lymphatics of the parenchyma of the breast.** These lymphatics originate in a plexiform network in the interlobular spaces and also on the walls of the lactiferous ducts and from their origin the lymph vessels pass towards the nipple and the areola and end by opening into the *Sappey's plexus* which is a large lymphatic collection beneath the nipple and the areola. The sub-areolar lymphatic plexus

of Sappey also receives lymph vessels draining the nipple and the areola. The sub-areolar plexus is drained by two main lymph trunks, one from its inner part and one from its outer part. These unite to form a single trunk which goes to the anterior or pectoral group of axillary lymph glands. These two vessels receive each a vessel which brings lymph directly from the breast itself and not from Sappey's plexus.

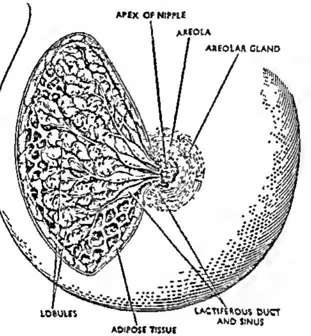


Fig. 772. A view of the interior of the right side of the breast during lactating period (Diagrammatic).

One of the lymph vessels from the supper and outer quadrant of the parenchyma of the breast, passes upwards, pierces the pectoralis major and clavi-pectoral fascia and ends in the apical group of axillary lymph gland. Some lymph vessels from the lower and inner quadrant of the parenchyma of the breast descend downwards to communicate with the sub-peritoneal lymphatics.

(2) **Lymphatics of the skin over the breast.** These lymphatics drain the whole of the skin over the breast except the nipple and the areola which drain into the Sappey's plexus. The distribution of these lymphatics from the different parts of the surface area of the breast may be conveniently put by dividing the breast into four quadrants, upper inner, upper outer, lower inner and lower outer by two imaginary planes, one vertical and one horizontal.

The lymphatics from the upper and outer quadrant pass in two directions, some opening into the infraclavicular lymph glands and some into the anterior or pectoral group of axillary lymph glands. The lymphatics from the upper and inner quadrant pass in three directions, some joining with the lymphatics of the opposite breast and some with the infraclavicular lymph glands; the rest accompany the internal mammary vessels and end in the internal mammary lymph glands. The lymphatics from the lower and outer quadrant pass in two ways, some joining with the anterior axillary lymph glands and some with the lymphatics of the abdominal parieties. The lymph vessels from the lower and inner quadrant pass in three directions; some cross the middle and end in the opposite breast, some in the internal mammary lymph glands and the rest in the lymphatics of the abdominal parietes.

(3) **Development of the mammary gland.** During the second month of intrauterine life the condensation of ectodermal tissue forms a ridgelike elevation,

the *mammary ridge* or the *"milk line"*, which extends from the axilla to the pubis and the inner aspect of the thigh. The *glandular part of the breast develops from this ectodermal ridge* as follows:

Opposite the future pectoral region there is a localised depression on this ridge which sinks below the level of the body surface. During the fifth month of intrauterine life a number of solid ectodermal cell buds extend backwards into the subjacent mesoderm. Each of these cell buds forms the future lobe of the mammary gland which further subdivides into different branches to form the lobule. Shortly before birth these cell buds are canalised to form the lactiferous duct. Subsequently the primary depression on the mammary ridge becomes evaginated to form the nipple into which the lactiferous ducts open. The remaining portions of the mammary ridge usually become atrophied in later periods.

The connective tissue storma of the breast is formed by the underlying *mesoderm* which, during the process of budding of the ectoderm, invests each lobe and the lactiferous duct and forms septa between the lobes. During fifth month on intrauterine life fat begins to appear in droplets in the interlobular spaces which later on aggregate together to form the typical fat.

In male subject usually no further changes take place after birth. In female during puberty there is further budding and branching of the lobular duct and there is much accumulation of fat to give the hemispherical contour of the breast. During pregnancy there is further increase in the number of the acini and there is more accumulation of fat.

N.B—Developmental errors—There may be complete absence of one or the other breasts giving rise to a condition known as *amastia*. Multiple breasts or *polymastia* on one or the other side opposite the mammary ridge have also been reported. Polymastia is natural in some animals, such as dogs, etc. Development of breast in case of male or *gynecomastia*, although very rare, occurs in some cases. Supernumerary nipples or *polythelia* are not uncommon.

Breast abscess may be either *subcutaneous*, *supramammary*, *intramammary*, *submammary* or *retromammary* affecting the respective tissues of the breast. In intramammary abscess different lobules are effected at a time and hence the abscess is usually loculated. Retromammary abscess is usually secondary to infection of the ribs or empyema of the chest.

In cancer breast retraction of the skin is due to fibrosis and subsequent shortening of the ligament of cooper while the retraction of nipple is due to dragging in of the lactiferous ducts by the surrounding fibrosis. Peau D'orange, is a condition in which there is oedema of the skin due to blockage of the lymph vessels with formation of pits on the skin opposite the hair follicles. This can be explained by the fact that the base of the hair follicle is adherent to the subcutaneous tissue and accumulation of lymph within the skin due to lymphatic obstruction causes it to be raised up in between the hair follicles. The bases of the hair follicles being fixed the opening of the hair follicle widens and this condition of the skin with pits and elevations resembling the skin of an orange is known as the Peau D'orange.

THE ENDOCRINE SYSTEM

THE PITUITARY GLAND

The pituitary gland is a neuro-glandular body suspended from the under-surface of the floor of the third ventricle by a projecting stalk—the infundibulum.

Measurement. It measures about 10-15 mm. transversely, about 11 mm. antero-posteriorly and about 6 mm. vertically. It weights about ·53 gm. in male and about ·62 gm. in the female. Larger in female and in those who have borne children than the male.

Situation. It lodges in the pituitary fossa or the sellae turcica of the sphenoid bone in the middle cranial fossa. A process of dura mater—the diaphragm sellae extends from the dorsum sellae to the tuberculum sellae and thus forms the roof of the pituitary fossa which is pierced by the infundibulum by means of which it is attached to the floor of the third ventricle.

Boundary of the cave of the pituitary body:

Posteriorly. It is overhung by the dorsum sellae with its posterior clinoid processes.

Anteriorly. It is overhung by the anterior clinoid processes and is related to the sphenoidal air sinus from which it is separated by a thin plate of bone.

Inferiorly. It is separated from the sphenoidal air sinus by a thin plate of bone.

Superiorly. It is roofed by the diaphragm sellae which is pierced by the infundibulum and separates it from the floor of the third ventricle and the optic chiasma. The latter comes into intimate relation with its roof.

Component parts. The pituitary gland is divided mainly into two parts, adenohypophysis and neurohypophysis. The *adenohypophysis* is further subdivided into pars distalis or anterior lobe, pars tuberalis, and pars intermedia. The *neurohypophysis* has been further subdivided into lobus nervosus and infundibulum, the latter consists of infundibular stem and median eminence of tuber cinereum. The so called posterior lobe consists of pars intermedia and the lobus nervosus, and the infundibulum together with the pars tuberalis constitutes the hypophyseal stalk. The table below shows the subdivisions of the pituitary gland.

- Pituitary gland
  - Adenohypophysis or the glandular lobe
    - Pars distalis or Anterior lobe
    - Pars Tuberalis
    - Pars Intermedia
  - Neurohypophysis or the Neural lobe
    - Lobus nervosus
    - Infundibulum
      - Infundibular stem
      - Median eminence of tuber cinereum

Posterior lobe=Lobus nervosus+pars intermedia.
Hypophyseal stalk=Infundibulum+pars tuberalis.

Relations. On either side it is related to the cavernous sinus which contains within its lumen oculomotor, trochlear and abducent nerves, the ophthalmic branch of the trigeminal nerve and the *internal carotid artery* with carotid plexus of sympathetic. Anteriorly it is related to the anterior intercavernous sinus which connects the two cavernous sinuses and posteriorly it is related to the posterior

intercavernous sinus. The circulus arteriosus forms a distant relation to it. The optic chiasma forms an important relation superiorly and lies against its roof.

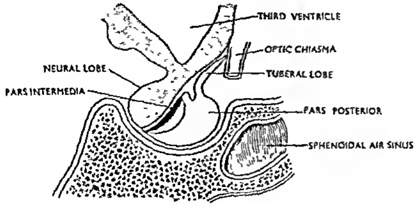


Fig. 773. The components of the pituitary gland.

The infundibulum attaches the pituitary gland to the inferior surface of the floor of the third ventricle and as it passes upwards it lies immediately posterior to the optic chiasma and is in contact with its posterior edge and undersurface.

Artery supply. It is supplied by the branches from the circulus arteriosus. The vessels pass along the infundibulum and then enter the gland. The anterior lobe is more vascular while the posterior lobe is less vascular.

Nerve supply. The posterior lobe is supplied by nerve fibres derived from the supra-optic nucleus. (Hypothalamic nucleus) and controls its antidiuretic effect.

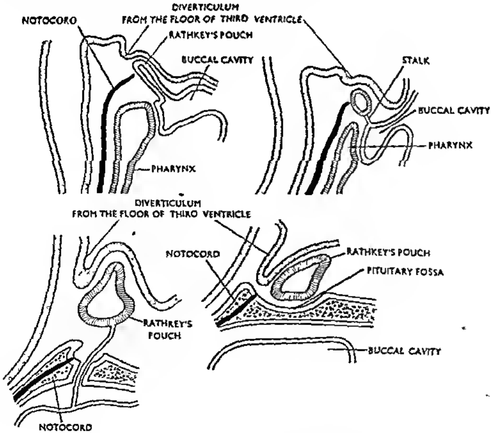


Fig 774. The development of the pituitary gland.

Development. The adenohypophysis or glandular lobe develops from an evagination in the form of a diverticulum from the buccal ectoderm known as the *Rathke's pouch.* The neurohypophysis is developed as a down-growth from the floor of the third ventricle and consists of nervous elements. The stalk of the Rathke's pouch becomes disconnected later on and the adenohypophysis becomes fused with the neurohypophysis whose stalk remains patent.

Structure of the pituitary body. ADENOHYPOPHYSIS. The *pars distalis* or the *anterior lobe* consists of a dense collagenous capsule, a supporting connective tissue framework containing reticular fibres, sinusoidal blood vessels and irregular *cords* and *masses* of glandular substance.

The cell-types are chromophile cells and chromophobe cells. The chromophile cells are further subdivided into *alpha* and *beta cells* according to the staining reaction of the specific granules of the cells (alpha with acid dyes, beta with basic dyes). The chromophobe cells are alternately called reserve cells or chief cells or 'C' cells and they *have no alpha or beta granules in their cytoplasm.*

In *pars intermedia* the original cleft may persist and on the anterior wall there is undifferentiated alpha, beta or C cells of one or two layers thick, in the posterior wall the cells form a thicker layer and consists of the same type of cells as on the anterior wall.

In *pars tuberalis* the cells are characteristically arranged in longitudinal networks of cords and balls of cells intermingled with blood vessels. The cell's types are a few alpha and beta cells and some undifferentiated cells.

The NEUROHYPOPHYSIS consists of a connective tissue network with rich capillary plexus, cell-nests of neuroglial cells and clusters of unmyelinated nerve fibres from the hypothalamo-hypophyseal tract. The cells of the neurohypophysis are called *pituicytes* which consist of 4 types namely adenopituicytes, micropituicytes, fibropituicytes and reticulopituicytes. The intercellular substance is abundant.

THE THYROID GLAND

The thyroid gland is one of the ductless gland situated in front and at the sides of the trachea opposite the fifth, sixth and seventh cervical vertebrae.

Measurements and weights. Each of the lateral lobes of the thyroid gland measures about 4 cm. in its vertical length, 2·5 cm. transversely opposite its greatest diameter and about 2 cm. in thickness. The isthmus of the gland measures about 2 cm. vertically. The average weight of the gland in the adult is 25 grams although it varies between 20 and 40 grams. It is slightly heavier in the females. The weight is, however, variable depending on the age, sex, climate, place and the nature of the food and the drink.

Capsules. The gland is provided with two capsules—true and false. The *true capsule* is formed by condensed mass of fibroareolar tissues surrounding the gland whereas the *false capsule* is formed by the pretracheal layer of the deep *cervical fascia.* A process of the deep cervical fascia extending from the deep aspect of the gland (ligament of Berry) connects it with the cricoid cartilage and thus firmly binds it with the larynx. Thus during deglutition it moves up and down with the larynx. The false capsule of the gland is very thin or deficient opposite the deep surface of the gland.

Parts for examination. The thyroid gland consists to two lateral lobes and occasionally a pyramidal lobe, and an isthmus connecting the two lobes together in front of the trachea.

LATERAL LOBE. Each lateral lobe is conical in shape and extends from the middle of the thyroid cartilage to the sixth tracheal ring. Each lobe presents a lateral or superficial surface, a medial or deep surface, a posterior or posterolateral surface and upper and lower ends or poles.

The *superficial* or *lateral surface* is covered by skin, superficial fascia, deep fascia, the sternohyoid, superior belly of the emohyoid and the sternothyroid muscles.

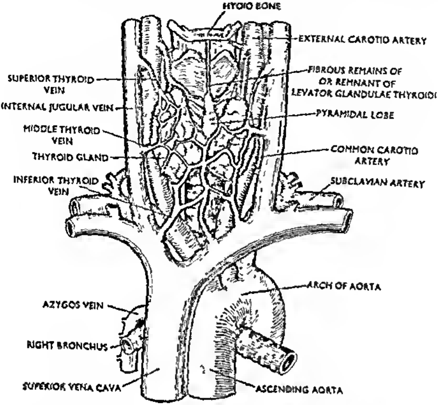


Fig. 775. The thyroid gland with the great vessels at the neck (seen from the front).

The *medial* or *deep surface* is moulded on to the sides of the larynx, trachea and oesophagus. This surface is related to two muscles, cricothyroid and inferior constrictor muscle of the pharynx, two nerves, recurrent laryngeal and external laryngeal nerves, two tubes, the trachea and oesophagus and the inferior thyroid artery with its branches. The recurrent laryngeal nerve forms a varying relation with this surface. In its course upwards, it usually lies behind the inferior thyroid artery but it may pass in front of it or it may be embedded in the substance of the gland. The external laryngeal nerve reaches this surface from above and lies behind the superior thyroid artery.

The *posterolateral* or *posterior surface* is related to the carotid sheath and overlaps the common carotid artery.

The anterior border is thin and is related to the anterior branch of the superior thyroid artery. Its posterior border is blunt and is in relation with the parathyroid glands.

The *pyramidal lobe*, which is the remains of the thyroglossal duct, extend upward for a variable distance either from the upper part of the isthmus or from any of the lateral lobes, more frequently from the left lobe. It may reach as high as the hyoid bone or it may be connected with the hyoid bone with a fibrous band. It may be completely replaced by a band of fibrous tissue. It may be absent completely when its place may be taken over by a muscular band or by a fibrous band extending into the hyoid bone; when this is muscular it is called the "levator glandulae thyroideae".

The ISTHMUS of the thyroid gland connects the two lateral lobes opposite the median plane and lies in front of the second, third and the fourth tracheal rings. It is covered in front by the skin, superficial fascia and the deep fascia and is overlapped on either side by the sternothyroid muscles. It measures about half an inch

in length and half an inch in breadth. Superiorly it is in relation to the arterial arch formed by the anastomosis of the branches of the two superior thyroid arteries. Inferiorly the inferior thyroid vein comes out from its lower border. Levator glandulae thyroidi, when it exists, connects the isthmus with the hyoid bone.

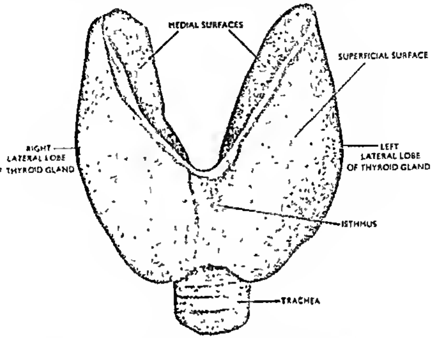


Fig. 776. The thyroid gland with a part of the trachea (seen from the front).

Vascular supply. The inferior thyroid artery supplies the parenchyma of the gland whereas the superior thyroid artery supplies the connective tissue element of the gland. The arteria thyroid ima, a branch of the arch of the aorta, may sometimes supply the gland.

The veins of the gland form a plexus which lies beneath the true capsule of the gland and is drained by the superior, middle and inferior thyroid veins. They run independent of the arteries. The superior and middle thyroid veins open into the internal jugular vein whereas the inferior thyroid vein opens into the innominate vein.

Lymphatic drainage. The lymphatics follow the blood vessels supplying the gland and terminate into pre-and paratracheal lymph nodes and into deep cervical and mediastinal lymph nodes.

N.B.—The thyroid gland is extremely vascular and it has been calculated that in a single minute, for each 100 grames of gland substance, about 560 c.c. of blood circulate through it and thus it is about 5½ times more vascular than the kidney.

Nerve supply. The nerves are derived from the middle and inferior cervical sympathetic ganglia.

N.B.—All tumors of the thyroid gland move with the movement of the trachea and larynx because it is firmly adherent to the cricoid cartilage by the ligament of Berry. The above anatomical facts help in differentiation of an enlarged thyroid gland from the enlarged deep cervical lymph nodes which do not move with the movement of the trachea during deglutition. The capsule of the gland being thin or deficient opposite its deep surface hypertrophy of the gland first starts in this surface and enlargement of this surface will invariably displace the trachea and the oesophagus to the opposite side. The venous plexus being situated in between the gland and the capsule, when removal of the gland is necessary it is removed along with its capsules in contrast to the removal of the prostate gland where the gland is enucleated out of its true capsules because in this gland the prostatic venous plexus lies in between its true and false capsules.

Sympathetic fibres are derived from the superior cervical sympathetic ganglion and the parasympathetic fibres are derived from the vagus through the thyroid nerve —a branch from the external laryngeal nerve.

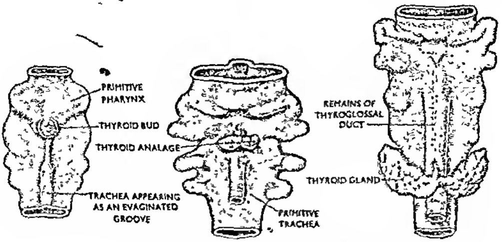


Fig. 777. The development of the thyroid gland.

Development. The thyroid gland develops during fourth month as an entodermal outgrowth from the floor or the anterior wall of the primitive pharynx. The entodermal outgrowth begins as a localised thickening on the ventral wall of the pharynx opposite the median plane and soon becomes evaginated to form a diverticulum which lies just caudal to the point where the tuberculum impar appears. The diverticulum enlarges and becomes a small bi-lobed flask-like structure which is connected with the floor of the buccal cavity by a narrow duct, the *thyroglossal duct.* Later on, the hollow diverticulum becomes a solid cord of cells, its connecting stalk elongates and its bi-lobed character becomes more prominent. With subsequent growth, the thyroglossal duct ruptures in its middle part, and the developing gland, which now forms a bi-lobed mass of cells, is draped in front of the upper part of the developing trachea.

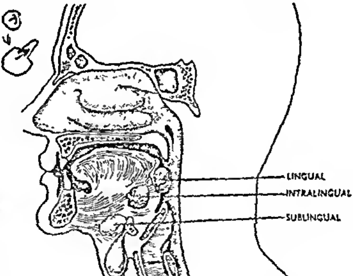


Fig. 778. Positions of the aberrant thyroid tissues (Diagrammatic).

Sites of aberrant thyroid tissue. Due to errors in migration the thyroid tissue may be found to be localised in any of the following sites opposite the middle line of the body:

Lingual—over the dorsum of the tongue.
Intralingual—with the musculature of the tongue.
Sublingual—below the tongue and in front of the hyoid bone.
Prelaryngeal—in front of the larynx.
Intratracheal—within the trachea.
Intraoesophageal—within the oesophagus.
Intrathoracic—within the thorax—usually behind the manubrium sterni.

In some rare cases, the aberrant thyroid tissue may be found to be migrated sidewards away from the middle line either in the submandibular region or in the supraclavicular region.

Histology. Histologically the thyroid gland consists of *follicles or acini*, *interfollicular tissue* and *connective tissue capsules*.

The follicles or acini are roughly rounded or elongated, sac-like hollow structures, completely closed from one another and contain in their lumen a variable amount of colloid substance. In other words, the follicles are the structural units of the thyroid gland. A normal follicle measures from 0·05 to 0·5 mm. in diameter.

Fig. 779. The structure of the thyroid gland.

Each follicle consists of a surrounding wall and a cavity. The surrounding wall is formed by a single layer of medium sized or low cubical epithelial cells which have no basement membrane, the cells resting upon the interstitial connective tissue which appears to be slightly condensed than the rest. The lumen of the follicles contain a variable amount of colloid substance.

The cells are of two types, chief cells and colloid cells. The chief cells stain fainty and they have large vesicular nuclei situated close to their bases. The colloid cells are deeply staining cells (with acid dyes) and their nuclei are more dense and are situated more centrally. These two types of cells are supposed to be the same cells in different functional stages.

The interfollicular tissue is relatively small in amount and contains the connective tissue stroma and some nests of thyroid epithelial cells having no lumen or having a very small lumen. The stroma contains a thin layer of connective tissue in which the blood vessels, nerves and lymphatics run and it also contains some lymphocytes and some of the reticulo-endothelial cells.

THE PARATHYROID GLANDS

The parathyroid glands are four small oval bodies, two on each side which are arranged in superior and inferior pairs and are situated in close relation with the posterior border of the lateral lobe of the thyroid gland close to the pharynx or oesophagus. Each body measures about 3 to 8 mm. in length, 2-5 mm. (5-7 mm.) (greatest diameter) in breadth and 0·5 to 2 mm. in thickness. They are yellowish brown in colour and of smoother consistency. The combined weight of the four bodies varies between 0 05 and 0·3 grams. The superior parathyroid bodies or the parathyroids IV are smaller than the inferior bodies and are situated at the junction of the upper-and middle-thirds of the posterior border of the lateral lobe of the

thyroid, one on each side, and each is embedded in the capsule of the gland. The inferior parathyroid bodies or the parathyroids III are situated on the posterior surface of the lower poles in relation with the inferior thyroid arteries. Each gland has a distinct hilum through which vessels and nerves enter into the gland. In some mammals such as in dogs, cats and rabbit, the parathyroids are usually found embedded in the thyroid gland but in Man it is very rare to see the parathyroids to be embedded in the thyroid tissue.

Vascular supply. The arteries supplying each gland are derived from the inferior thyroid artery or from the anastomosing channel between the superior and inferior thyroid arteries. The veins drain into adjacent large veins (?).

Nerve supply. The nerves supplying the glands are non-medullated nerves and are derived from the recurrent laryngeal and external laryngeal nerves. The superior parathyroids are supplied by branches from external laryngeal branch superior laryngeal whereas the inferior ones are supplied by branches from the recurrent laryngeal nerves. The nerves are vasomotor in function and have no direct relation with the secretion of the glands.

Development. The parathyroid bodies are derived as diverticula from the dorsal parts of the third and the fourth pharyngeal pouches, the superior parathyroid bodies from the fourth and the inferior ones from the the third pharyngeal pouches. Depending on the origin, the superior parathyroid bodies are alternatively called parathyroids IV and the inferior ones as parathyroid III. The inferior parathyroid bodies though derived from the third pharyngeal pouches assume a caudal position (In relation to superior parathyroids derived from fourth pharyngeal pouches) due to its caudal migration in association with the thymus gland which is also derived from the third pharyngeal pouches.

Structure. Each gland is surrounded by a capsule which sends in delicate processes within the gland so as to form a fine retinaculum (St oma) within which epitheloid cells are confined. With advancing age the stroma increases in amount and the delicate retinacula of earlier age form septa-like processes which give the gland a lobulated appearance. Considering the size of the gland numerous large blood sinuses pervade through the gland substance. Thus for all practical purposes the gland is found to consist of masses or columns of epitheloid cells with large blood sinuses in between.

The epitheloid cells are of three types, non-granular or clear principal cells and granular, acidophil and eosinophil or oxyphil cells. The clear principal cells are spherical cells with large vesicular nucleus and clear cytoplasm. The acidophilic cells show the presence of granules in their cytoplasm which stain weakly with acid dyes so as to give the cell a dark appearance. The eosinophil or oxyphil cells the largest cells and contain granules in their cytoplasm which present bright red appearance with acid dyes and the nucleus of these cells are much smaller in comparison with the other two types of cells. Colloid vesicles may also occur in one of the cells particularly with advancing age but these vesicles have no iodine.

THE SUPRARENAL GLANDS

The suprarenal glands or bodies are two in number, each being placed on the upper pole of the corresponding kidney. It is one of the most important ductless gland and influences bodily functions in a variety of ways. *Anatomically* each suprarenal body is a single gland but *functionally* and *developmentally*, it is a combination of two glands in one consisting of two functional units, the cortex and the medulla. Structurally the cortex is distinct from the medulla and surrounds the latter externally, in other words, the suprarenal body consists of an outer cortex and an inner medulla.

Shape and form. The two suprarenal glands differ from each other in shape. The right is triangular and the left is semilunar in shape. Each comes into direct

contact with the upper pole of the corresponding kidney but is easily separable from it. The right suparenal gland is more adherent on to the posterior surface of the liver or to the inferior vena cava while the left is more adherent to the left crus of the diaphragm. This explains why the suprarenal gland is not displaced in case of displacement of the kidney.

Capsules. Each suprarenal gland has two capsules--true and false. The true capsule is formed by the condensed mass of fibroareolar tissues surrounding the gland and the false capsule is formed by the renal fascia. In between the two suprarenal glands there lie the coeliac artery and the coeliac ganglion and each is placed at a distance of about one inch from the artery.

Measurements and Weights. Each suprarenal gland measures about one to two inches in length, one inch in breadth and about one fourth inch in thickness. Each is about 1 dr. in weight.

Right suprarenal gland. The right suprarenal gland is triangular in shape with its apex directed upwards and the base downwards. Just below the apex the anterior surface presents the hilum through which only the right suprarenal vein comes out of the gland. Medially the anterior surface is overlapped by the inferior vena cava and is devoid of peritoneal covering. Laterally and above, the anterior surface is attached to the bare area of the liver by areolar tissue and laterally and below, it is covered by the peritoneum of the lesser sac. Posteriorly it is related to the right crus of the diaphragm above and with the upper pole of the right kidney below. The medial margin of the gland is in relation to right coeliac ganglion and the right inferior phrenic artery.

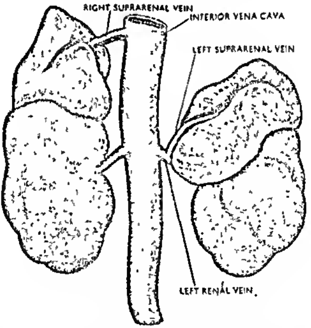
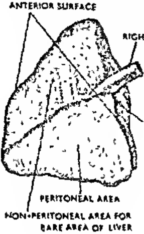


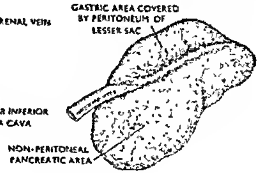
Fig. 780. The developing kidney with the suprarenal gland together with the inferior vena cava. With kind permission from the Govt. of West Bengal and the professor of Anatomy Cal. Medical College.

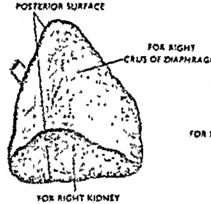
Left suprarenal gland. The left suprarenal gland is semilunar in shape and forms a broad and expanded base directed downwards and a tapering apex directed upwards. Its lateral border is concave and its medial margin is convex. The anterior surface of the left suprarenal gland presents the hilum opposite to its lower expanded base close to the medial margin and transmits the left suprarenal vein.

Superiorly the anterior surface is covered by peritoneum of the lesser sac which separates it from the postero-inferior surface of the stomach. The lower part of the anterior surface is in relation with the tail of the pancreas and the splenic vessels.

Fig. 781. The front view of right suprarenal gland. Fig. 782. The front view of left suprarenal gland.







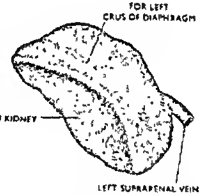


Fig. 783. The back view of right suprarenal gland. Fig 784. The back view of the left suprarenal gland.

Its posterior surface is hollowed out laterally which fits into the medial margin of the upper pole of the left kidney. The medial area of the posterior surface is separated from the lateral grooved or hollowed out area by a rounded ridge and is adherent to the left crus of the diaphragm. The ridge on the posterior surface may correspond to a faint shallow groove on the anterior surface and together with the left suprarenal vein it resembles a leaf in appearance. Its medial convex margin is in relation to the left coeliac ganglion, left inferior phrenic and the left gastric arteries.

Artery supply. Each suprarenal gland is supplied by three suprarenal arteries:—(a) superior suprarenal branch of inferior phrenic, (b) middle suprarenal branch of abdominal aorta, and (c) and inferior suprarenal branch of renal artery.

Veins. The right suprarenal vein ends in the inferior vena cava whereas the left suprarenal vein opens into the left renal vein.

Nerve supply. Each suprarenal gland is supplied by splanchnic nerves (preganglionic fibres) through coeliac and renal plexuses. According to some authority it also receives some branches from the phrenic and vagus.

Lymphatics. The lymph vessels draining the suprarenal gland accompany the suprarenal arteries and the vein and they terminate in the para-aortic lymph nodes.

The lymphatics draining the medulla accompany the suprarenal vein whereas the lymphatics draining the cortex accomapny the arteries supplying the gland.

Development. The coelomic epithelium close to the root of the dorsal mesentery gives rise to the formation of the cortex of the suprarenal gland (Mesodermal origin) whereas the migrated sympatho-chromaffin cells from the neural crest give rise to the formation of the medulla of the suprarenal gland (Ectodermal origin). The cortex develops in situ from the mesoderm of the intermediate cell mass.

Structure. The adrenal body consists of a connective tissue *capsule*, which sends in *traboculae* within the gland, an outer cortex and an inner medulla and a rich network of blood vessels.

The *cortex* consists of epitheloid cells which are arranged into three layers from without inwards namely zona glomerulosa, zona fasciculata and zona reticularis.

The *Zona glomerulosa* consists of columnar cells which are closely packed together either in columns or in ovoid masses beneath the connective tissue capsule.

The *Zona fasciculata* consists of polyhedral cells which are arranged into anastomosing cords and lie deep to the zona glomerulosa.

The *Zona reticularis* is the deepest layer which overlies the medulla and consists of anastomosing cords of cells.

The **medulla** consists of irregular cells which are arranged into short cords or rounded lumps and are surrounded by blood vessels. These cells show *chromaffin reaction* in which fine brown granules are seen within their cytoplasm when fixed in a fluid containing potassium dichromate.

N.B.—It will be interesting to note that artery and vein do not pass together through the hilum, but the vein only emerges through it and the arteries supplying it pierce its surface from different positions and they are comparatively rich in supply. The medial medullary part of the gland which is derived from the sympatho-chromaffin cells is responsible for the secretion of adrenalin which plays its usual roll on the sympathetics whereas the cortex is concerned with the metabolism of salt and water and directly or indirectly influences the secondary sexual characters.

THE OVARIES

The ovaries are the two flattened bodies homologous with testis in male, situated one on each side of the uterus. It is attached to the posterior surface of the broad ligament by a fold of peritoneum known as the mesovarium and lies on the lateral wall of the pelvis in a shallow depression—the ovarian fossa.

Each ovary occupies a peritoneal recess, the *ovarian fossa* on the lateral wall of the pelvis. It is bounded in front by the obliterated umbilical artery and behind by the ureter and the internal iliac artery. The floor is formed by the parietal peritoneum of the pelvic cavity which separates it from the obturator vessels and nerves.

The dimension of the gland in women who have not been pregnant are 3 cm. long, 2 cm. from before backwards and 1 cm. transversely.

Each ovary consists of two surfaces—a lateral and a medial, two borders—a mesovarian or attached border and a free border, two ends a tubal end and an uterine end.

The *lateral surface* lies in contact with the floor of the ovarian fossa and is separated from the obturator vessels and nerves by the parietal peritoneum.

The *medial surface* is overlapped by the uterine tube and the space between this surface and the mesosalpinx is known as the *bursa ovarica*.

The mesovarian or attached border is straight and is attached to the uterine tube by means of a double fold of peritoneum known as the *mesovarium*. The hilum of the ovary lies in this border through which the ovarian vessels and nerves enter the gland.

The free border is rounded and convex and is directed towards the ureter.

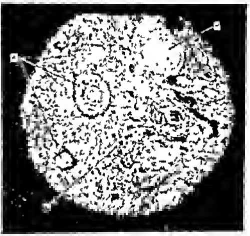
The *tubal extremity* of the ovary is directed towards the infundibulum of the uterine tube and is connected with the lateral wall of the pelvis by a double fold of peritoneum known as the infundibulopelvic ligament (suspensory ligament of the ovary) which contains in between its two layers, the ovarian vessels and nerves.

The ovarian fimbria connects the tubal end of the ovary with the uterine tube and the discharged ova is carried to the tube by means of this ovarian fimbria.

The *uterine end of the ovary* is connected with the lateral angle of the uterus by means of a cord-like structure, the ligament of the ovary which passes between the two layers of the broad ligament and lies below and behind the uterine tube.

Vascular supply. The artery supplying the ovary is the ovarian branch of the abdominal aorta. The veins draining the ovary arrange in a plexiform network known as the pampiniform plexus, which ultimately unite to form a single vein and opens into the inferior vana cava on the right side and into the left renal vein on the left side.

Nerve supply. The nerves supplying the ovary are derived from both the sympathetic and parasympathetic nerves and accompanying the ovarian artery they enter into the hilum of the ovary.



A—The developing ovum.
B—Corpus albicans.
C—Stroma.

Fig. 785. The histological structure of the ovary (Microphotograph).

Structure. Each ovary consists of a cortex and a medulla. The *Cortex* surrounds the medulla except the hilum and consists of follicles of various sizes (for details of structure of the follicles, see ovulation). The *medulla* consists of lose connective tissue and numerous blood vessels.

THE TESTES

The testes are the reproductive glands in the male and are suspended into the scrotum by the spermatic cord.

Each testis is oval in shape and is placed obliquely in the scrotum with its upper pole titled slightly forwards and laterally. Each testis measures about two inches in length, one inch in breadth and about one and one-fourth inches in thickness. It varies from 4 to 5 dr. in weight. The left testis descends slightly to a lower level than the right. Superiorly and postero-laterally the epididymis is intimately connected with it.

Coverings of the testis. From without inwards the coverings of the testis are the visceral layer of the tunica vaginalis, the tunica albuginea and the tunica vasculosa. The visceral layer of the tunica vaginalis is derived from the peritoneum and receives this investment during its descent from the abdominal cavity and forms the lower portion of the processus vaginalis in the foetal life. The tunica albuginea is a tough fibrous membrane while the tunica vasculosa is formed by a plexus of blood vessels held together by delicate areolar tissue.

Each testis has got a lateral and a medial surface, and an anterior and a posterior border and two ends, upper and lower and an epididymis.

The **lateral surface** is more convex while the **medial surface** is almost flat. The **anterior border** is convex and rounded and is directed forwards and downwards. The **posterior border** is straight and gives attachment to the epididymis in its lateral part.

The **epididymis** is attached to the **lateral** part of the posterior border of the testis and consists of a head, a body and a tail. The head of the epididymis is formed

by its upper expanded part which is connected with the testis by the efferent ducts of the latter. The body of the epididymis overlaps on to the lateral surface of the testis and is separated from it by a recess, the *sinus of the epididymis.* Holding the testis by the spermatic cord which looks posteriorly, the sinus of the epididymis determines the side to which the testis belongs. The tail occupies the lower part of the posterior border and is narrow and constricted. It is fixed to the testis by areolar tissue and is directly continuous with the vas deferens. One small sessile body, the *appendix of the testis,* is attached to the upper pole of the testis and represents the embryonic remnant of the upper end of the paramesonephric duct. Another pedunculated body, occasionally found on the head of the epididymis, is known as the *appendix of the epididymis* and represents the embryonic remnant of mesonephric body.

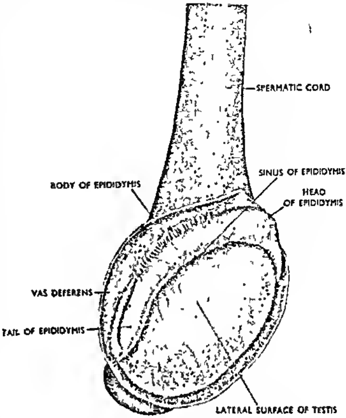


Fig. 786 The right testis seen from the lateral side.

Vascular supply. The testicular branch of the abdominal aorta, the artery to the vas, a branch of the inferior vesical, and the cremasteric branch of the inferior epigastric artery supply the testis. The veins draining the testis form a plexus, the pampiniform plexus which is drained ultimately by a single vein which on the right side opens into the inferior vena cava and on the left side into the left renal vein.

Nerve supply. Nerves supplying the testis are derived from the tenth thoracic segment of the spinal cord through aortic and renal plexuses.

Lymphatics. The lymph vessels from the testis accompany the spermatic cord and enter the abdominal cavity along with the vas deferens and then accompanying testicular artery they end in the aortic group lymph nodes.

General structure. Externally the testis is lined by the visceral layer of the tunica vaginalis and subjacent to it there lies its fibrous tunic. The fibrous tunic of the testis, formed by the tunica albuginea becomes thicker and condensed posteriorly and is known as the *mediastinum testis* through which the blood vessels and lymphatics make their way. From the mediastinum testis numerous fine septa pass within the testis which subdivide it into about 250 irregular compartments or lobules. In each lobule there are two or more thread-like *seminiferous tubules.* Each seminiferous tubule is about 2 feet long and is much convoluted to form the *convoluted seminiferous tubules* which produce the sperm cells. In the apex of the pyramidal-shaped lobule or compartment the seminiferous tubules take up a straight course to form the *straight seminiferous tubules.* In the mediastinum testis the straight seminiferous tubules from different compartments form a network known as the *rete testis.* From

the upper part of the rete testis about six to twelve ducts, the *efferent ductules*, each of which measures about 4 to 6 cm. in length pass to the head of the epididymis.

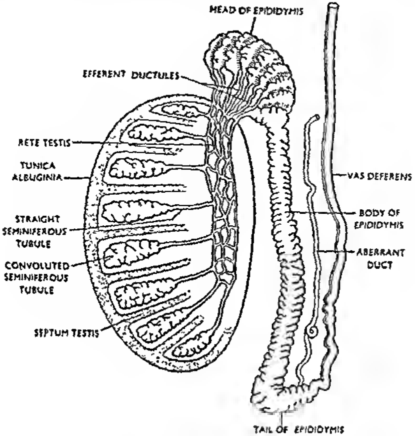


Fig. 787. The structure of the testis (Diagrammatic).

Specific structure. The testis being the male reproductive organs they are mainly concerned in the production of sex cells and the sex hormones. The seminiferous tubules are concerned with production of sex cells whereas the interstitial tissues are concerned with the elaboration of the sex hormones. Thus basically, the specific structures of the testis are the *seminiferous tubules* and the *interstitial tissue*.

Seminiferous tubules. Each seminiferous tubule is a tubular structure having a lumen within and a surrounding wall. The surrounding wall is formed by a thin connective tissue membrane, the *basement membrane.* The basement membrane supports two types of cells, the *spermatogenic cells* or the *spermatogonia*, and the *supporting cells* or the *Sertoli cells*.

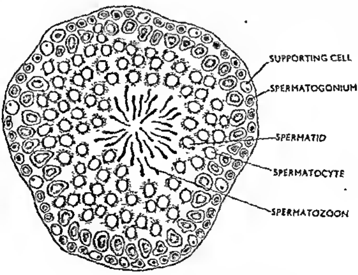


Fig. 788. The structure of a seminiferous tubule (Enlarged and Diagrammatic).

The *spermatogenic* cells or the *spermatogonia*. The are germinal epithelial cells of the tubule and greatly out-number the supporting cells and form closely packed layers of cells in relation to the basement membrane.

The *supporting cells* or the *Sertoli cells*. The Sertoli or the supporting cells of the seminiferous tubule are tall, slender cells which are placed perpendicularly to the basement membrane in between the spermatogenic cells. They may undergo change in shape and may be rounded to be transformed into phagocylic cells which engulf the dead and the degenerating spermatogenic cells. They are also believed to concerned in some way in the metamorphosis of the spermatid into spermatozoa.

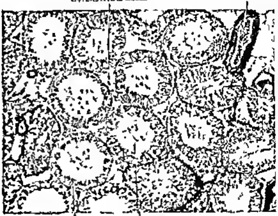


Fig. 769 The histological structure of the testis (Microphotograph).

The Interstitial tissue. The interstitial tissue lies in between the seminiferous tubules and consists of *connective tissue cells* and *fibres, interstitial cells* or *cells of Leydig, blood vessels, lymphatics* and *nerves*. The *interstitial cells* are large polyhedral cells with large nucleus and granular cytoplasm and are concerned in the production of the male sex hormone.

Structure of the epididymis. Each of the efferent ductules is convoluted to form a mass, the lobule of the epididymis and different lobules of the efferent ductules unite to form the *head of the epididymis*; from the head of the epididymis efferent ductules unite below to form the *canal of the epididymis*. The canal of the epididymis which measures about 20 ft. in length is folded many times upon itself to form a compact mass, the *body and tail of the epididymis*. The vas deferens, which is the efferent duct of the testis, begins from the canal of the epididymis opposite its tail.

Development. The developments of the testis are threefold. (1) The convoluted seminiferous tubules, the straight seminiferous tubules and the rete testis develop from the genital ridge opposite the fourth lumbar to second sacral segments during the sixth week of foetal life. The cells of the genital ridge proliferate to form cords of cells known as the medullary cords which are united together to form a series of cord-like structures known as the rete cords. The rete cords are canalised subsequently. (2) The efferent ductule and the lobule of the head of the epididymis develop from six or more mesonephric tubules which later on establish communication between the rete testis and the canal of the epididymis. (3) The canal or the duct of the epididymis and the vas deferens are developed from the mesonephric ducts (Wolffin ducts).

Gubernaculum testis. It is a cord-like structure of spindle-shaped cells which develop in association with the testis. Its upper end splits into three processes, each being attached to the adjacent peritoneum, to the testis and to the mesonephric ducts. It passes through the growing abdominal wall and its lower end splits up into numerous process or strands of varying length which are attached to the scrotum, perineum, root of the penis, inner side of the thigh and also to the adjacent parts.

Descent of the testis. As growth follows, the gubernaculum testis gradually shortens, and its lower end having extensive attachment, acts as a fixed point and, as it gradually shortens, it drags the testis, the peritoneum and the mesonephric duct. A balanced traction from different strands of the gubernaculum testis drags the testis, peritoneum and the mesonephric duct through inguinal canal to the scrotal

sac. The peritoneum being dragged, a tubular peritoneal pouch known as the *processus vaginalis* follows the testis and its duct into the scrotum. Later on, the walls of the processus vaginalis fuse together and the canal is obliterated.

During the third month of foetal life the testis comes down to the iliac fossa, during the seventh month to the inguinal canal and finally it reaches the bottom of the scrotum at or soon after birth.

N.B.—Due to irregular traction the testis may not come out of the abdominal cavity at all or it may be lodged somewhere in the inguinal canal or it may descend into the inner side of the thigh or its complete descent may be unusually delayed.

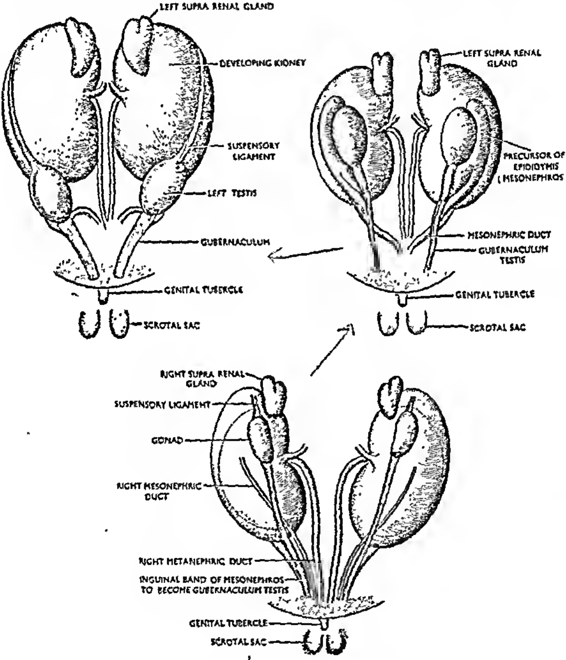


Fig. 790. The descent of the testis.

Collection of serous fluid within the serous layer of the testis gives rise to enlargement of the scrotum causiog a condition known as *hydrocele.* When the

fluid collects in between the parietal and visceral layers of the tunica vaginalis it is known as the *vaginal hydrocele.* Soon after birth the layers of the processus vaginalis are fused together and its lumen is shut off from the general peritoneal cavity. In some cases the processus vaginalis remains patent and a collection of fluid into a

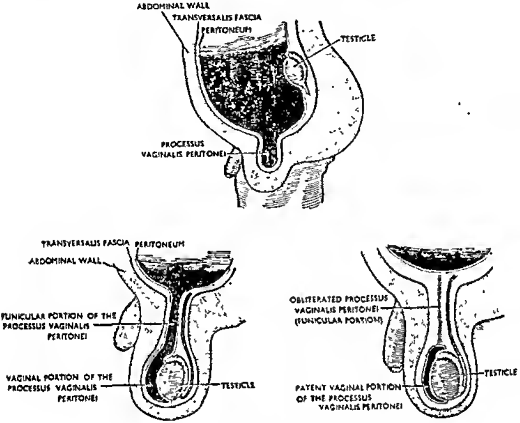


Fig 791. The further stages in the descent of the testis

patent vaginal sac is known as the *congenital hydrocele.* In some cases the processus vaginalis is shut off from the peritoneal cavity but it remains patent below and a collection of fluid into the vaginal sac under this condition is known as the *infantile hydrocele.* Here the scrotal swelling extends upwards along the spermatic cord. Sometimes the processus vaginalis is obliterated both at the deep inguinal ring and opposite the head of the epididymis but remains patent in the intermediate portion and a collection of fluid into this patent sac is known as the *encysted hydrocele of the cord.* Sometimes localised swelling on the head of the epididymis is known as the encysted hydrocele of the epididymis or spermatocele.

Testicular anomalies. The anomalies in the development of the testis may be considered under the following heads:—

(1) *Anomalies of position.* Normally the testis is obliquely placed within the scrotum with it upper pole directed upwards and forwards. Any deviation from the usual position and direction of the upper pole of the testis is known as *inversion of the testis.* In some cases the upper pole rotates forwards in which it is directed directly forward and the testis lies in a horizontal position (anterior rotation). In some the upper pole is rotated backwards (posterior rotation).

(2) *Anomalies of number.* Although it is very rare, there may be complete absence of testis on both the sides giving rise to a condition known as *Anorchidism.* Sometimes there is only one testis and the condition is known as *Monorchidism.* There

may be one or more supernumerary testes with their excretory ducts (epididymis, vas deferens etc.) and such conditions are known as *polyorchidism*.

(3) *Anomalies of descent.* The descent of the testis may be arrested at any point in its normal path of descent giving rise to a condition known as *cryptorchidism* which may be either unilateral (commoner, 1 in 500) or bilateral. The cryptorchidism may be of *suprainguinal* or *abdominal*, *inguinal* and *subinguinal types*. In suprainguinal type of cryptorchidism, the descent of the testis is arrested within the abdomen, in inguinal type, in the inguinal canal and in subinguinal type, between the subcutaneous inguinal ring and the scrotum.

In cryptorchidism, the affected testis lacks in usual development and is smaller in size. Spermatogenesis fails to occur and the organ often becomes the seat of malignancy and new growths.

(4) *Abnormal migration.* In this, the testis migrates from its normal path to some abnormal situation giving rise to a condition known as *ectopia testis* or *aberrant migration*. In ectopia testis, the position of the organ is extremely variable and the following varieties of the ectopia testis have been detected according to its location.

(a) *Pelvic.* Descending in the true pelvis.
(b) *Inguinal.* Lies under the skin of the abdomen above the inguinal ligament.
(c) *Penile.* It may descend to the root of the penis or it may lie under the skin of the penis.
(d) *Perineal.* It may be located in the perineum.
(e) *Femoral.* It may lie in the femoral canal or under the skin in the femoral triangle.
(f) *Transverse ectopia.* In this the testis is located in the opposite scrotal sac.

Age changes. *At birth* the testis weighs only about 2 grms. and it then slowly increases in size until puberty when it starts growing rapidly and at the end of puberty it gains about 100 times its birth weight. *Before puberty*, the seminiferous tubules are not canalised and spermatogenesis does not occur; the matrix between the tubules are formed by undifferentiated connective tissue cells; in a tubule, the cells of Sertoli outnumber the germinal cells. At puberty, the seminiferous tubules become canalized, the germinal cells outnumber the cells of Sertoli and spermatogenesis begins; specific interstitial cells differentiate in the matrix between the tubules and begin to secrete androgenic hormone.

The Vas deferens. It is the direct continuation of the canal of the epididymis and at its origin it is very tortuous and ascends upwards on the medial side of the epididymis along the posterior border of the testis. From the upper pole of the testis it becomes straight and passes upwards along the posterior border of the spermatic cord to the superficial inguinal ring and enters the inguinal canal. Then it reaches the deep inguinal ring where it is separated from the other constituents of the spermatic cord and enters the abdominal cavity through the deep inguinal ring on the lateral side of the inferior epigastric artery. In the abdomen, it at first runs forwards in front of the external iliac vessels for about 2·5 cm. and then descends downwards and backwards and crosses in front of the external iliac vessels. Then it descends downwards and medially on the lateral wall of the true pelvis under cover of the parietal peritoneum and lies on the medial side of the obturator, umbilical and vesical vessels. Then it crosses the ureter to gain its medial side and descends to the base of the bladder to reach the upper end of the seminal vesicle and gradually approaches the vas deferens of the opposite side. Here it is separated from the rectum by the rectovesical fascia. Then it reaches the basal surface of the prostate where it unites with the duct of the seminal vesicle to form the ejaculatory duct which passes through the posterior part of the median lobe of the prostate and ends by opening into the prostatic portion of the urethra on either side of the prostatic utricle. Close to the base of the bladder it forms a dilatation known as the ampulla.

It is the excretory duct of the testis and carries the semen to the seminal vesicle and then to the prostatic portion of the urethra.

THE THYMUS

The thymus is a bilobed vascular type of ductless gland and is a derivative of the ventral ends of the third pharyngeal pouches. Being a vascular gland it is of pink colour.

Situation and extent. It is situated mainly within the thorax in the superior and anterior mediastinums and partly into the root of the neck and extends from the level of the cricoid cartilage upto fourth costal cartilage. Within the thorax it intervenes between the back of the sternum in front, and the pericardium and the great vessels behind, and in the root of the neck, between sternohyoid and sternothyroid muscles in front and the trachea behind.

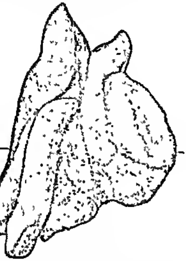


Fig 792. The thymus gland as seen from the front

Shape and size. Both shape and size are extremely variable from man to man, from man to woman and at different ages of life in the same individual. Its shape is mostly dependent on its size and usually takes the shape of the mould formed by the surrounding structures. In the infants its lobes are pyramidal in shape and are broader below. In the adult it forms two irregular, flattened elongated bands.

Weight. At birth it weighs about 13 grms., at puberty about 37 grms. and in the adult about 30 grms. on average.

Parts for examination. The gland is surrounded by a fibrous capsule and consists of two asymmetrical lateral lobes which lie in close apposition with each other and are held together by loose areolar tissue and usually presents a line of cleavage between the two lobes. Its surfaces are anterior and posterior and present a lobulated character.

Relations. *Anteriorly*, it is related to the back of the upper part of the body of the sternum, the back of the manubrium sterni and the lower part of the sternohyoid and sternothyroid muscles. *Posteriorly*, it lies successively upon the pericardium, ascending aorta, arch of the aorta, left brachiocephalic vein, and the trachea, the inferior thyroid vein intervening between the trachea and the gland. In the thorax, the gland lies just in front of the trachea but at the root of the neck it lies at its antero-lateral part.

When the thymus is of considerable size, as in the infant, it extends laterally beyond the sternum and insinuates between the costal pleura and the anterior margin of the lung and its lateral portion is related in front to the back of the costal cartilages (upto 4th costal cartilage), intercostal spaces (1st, 2nd and 3rd) and the internal thoracic artery being separated by the costal pleura. Posteriorly the lateral portion is related to the anterior margin of the lung being separated by the parietal pleura.

Vascular supply. The arteries supplying the gland are the thymic branches from the internal thoracic and the superior and inferior thyroid arteries. The veins open into brachiocephalic, thyroid and internal thoracic veins.

Lymphatics. The lymph vessels from the gland end into innominate lymph nodes.

substance known as the substantia gelatinosa centrali around which there lies the grey commissure of the medulla spinalis. Its inner surface is lined by ventricular ependyma and it contains the cerebro-spinal fluid. In the lower part of the conus medullaris it forms a fusiform dilatation known as the *terminal ventricle* and measures about half an inch in length.

Different tracts in the spinal cord

(1) In the anterior white column—
- (*a*) Anterior spino-thalamic tract.
- (*b*) Anterior cerebro-spinal tract (uncrossed pyramidal).
- (*c*) Vestibulo-spinal tract.
- (*d*) Anterior intersegmental tract.

(2) In the lateral white column—
- (*a*) Lateral cerebro-spinal tract (crossed pyramidal).
- (*b*) Rubro-spinal tract.
- (*c*) Tecto-spinal tract.
- (*d*) Olivo-spinal tract.
- (*e*) Posterior spino-cerebellar tract.
- (*f*) Anterior spino-cerebellar tract.
- (*g*) Spino-tectal tract.
- (*h*) Lateral spino-thalamic tract.
- (*i*) Postero-lateral tract.
- (*j*) Lateral intersegmental tract.

(3) In the posterior white column—
- (*a*) Fasciculus gracilis.
- (*b*) Fasciculus cuneatus.
- (*c*) Semilunar tract (occupying the cervical and upper thoracic region only).
- (*d*) Dorsal peripheral strand.
- (*e*) Triangular strand.
- (*f*) Posterior intersegmental tract.

ASCENDING TRACTS OF THE SPINAL CORD. All ascending tracts of the spinal cord carry afferent impulses to the higher centres and these impulses, which they carry, are divided into two main groups as (1) Exteroceptive and (2) Proprioceptive impulses.

Exteroceptive impulses are caused by external agents and are appreciated by consciousness in the form of pain, heat, cold, touch etc. These exteroceptive sensations travel in the medulla spinalis by three principal ascending tracts, namely, anterior and lateral spino-thalamic tracts and the fasciculus gracilis et cuneatus.

Spino-thalamic tracts. The spino-thalamic tracts consist of anterior and lateral spino-thalamic tracts.

The *anterior spino-thalamic tract* transmits crude sensations with discriminative quality to the sensory area of the brain. It arises from the cells of the posterior horn of the opposite side and ascends upwards along the anterior white column to reach the medulla oblongata where it comes in close contact with lateral spino-thalamic tract.

The *lateral spino-thalamic tract* transmits painful and crude touch stimuli without any discriminative quality to the sensory area of the brain. It arises from the cells of the posterior horn and ascends upwards along the lateral white column to reach the medulla oblongata where it comes in close contact with the anterior spino-thalamic tract.

In the medulla oblongata the two tracts are grouped together to form the *spinal lemniscus* which ascends upwards to end into the anterior part of the lateral nucleus of the thalamus. From the thalamus relay fibres pass upwards through the

posterior limb of the internal capsule and finally end in the postcentral gyrus of the cerebral cortex.

Proprioceptive sensations or deep sensations originate in the muscle, tendon etc., and are not appreciated by consciousness. They consist of sensations of movements and posture and keep the higher centres well informed about the position of the body. These sensations travel through the fasciculus gracilis et cuneatus. In addition to the proprioceptive fibres the fasciculus gracilis et cuneatus carry some of the exteroceptive fibres which are concerned with discriminative impulses of pain, heat and touch sensibility and ascertain localisation of such sensations.

Fasciculus gracilis et cuneatus. The fasciculus gracilis arises from the posterior grey cells of the medulla spinalis and begins from the lowest limit of the same. It ascends upwards through the posterior white column and occupies its medial portion; it ends in the nucleus gracilis of the medulla oblongata.

The fasciculus cuneatus arises from the posterior horn cells and begins from the mid-thoracic region and ascends upwards through the lateral part of the posterior white column to end into the nucleus cuneatus of the medulla oblongata.

Relay fibres arise from the nucleus gracilis and cuneatus and form the *internal arcuate fibres* which decussate with the fellow of its opposite side, the *great sensory decussation*, in the upper part of the medulla oblongata and then ascend upwards as a distinct band known as the *medial lemniscus* and then passing through the tegmentum of the mid-brain they finally end in the ventral part of the lateral nucleus of the thalamus. Relay fibres from the thalamus pass through the posterior limb of the internal capsule and end into the post-central gyrus of the cerebral cortex.

The fibres of the fasciculus gracilis and cuneatus carry all the deep sensibility with the exception of the pressure and pressure pain sensations. They also carry discriminative impulses of pain, heat and touch sensibility. They are also concerned with localisation of sensations and characterise sensation of movement and posture.

Anterior spino-cerebellar tract. It lies close to the surface of the spinal cord ventral to the posterior spino-cerebellar tract and passes through the lateral white column of the spinal cord. Its fibres pass through the medulla and pons and then enter the cerebellum through the superior cerebellar peduncle and end in the superior vermis of the same.

Posterior spino-cerebellar tract. It also lies close to the surface dorsal to the anterior spino-cerebellar tract and ascends upwards in the lateral white column of the spinal cord. It enters the cerebellum through the inferior cerebellar peduncle and end in the vermis of the cerebellum.

Spino-tectal tract. Its fibres arise in the posterior horn cells and decussate with the fellow of the opposite side to reach the opposite lateral white column. Its fibres pass through the medulla and pons and finally end in the superior quadrigeminal body.

Descending Tracts. The descending tracts of the spinal cord constitute the efferent pathways from the cerebrum, cerebellum and corpus striatum, lower visual centre and from the vestibular nucleus. The fibres from the cerebrum constitute the cerebro-spinal tract and the fibres from the vestibular nucleus form the vestibulo-spinal tract. The following are the descending tracts:

(1) **Cerebro-spinal tract.** It has been described under the head "Pyramidal tract."

(2) **Rubro-spinal tract.** The rubro-spinal tract is the efferent pathway from the cerebellum and the corpus striatum. Its fibres arise from the corpus striatum and the cerebellum and pass to the red nucleus from where relay fibres arise and decussate with the fellow of the opposite side and descending downwards through the dorsal part of the pons and medulla they pass through the lateral white column of the spinal cord in close company with the crossed pyramidal fibres and finally end in the anterior horn cells of the same side.

Nerves. The fibrous capsule of the gland is supplied by branches from the phrenic nerves whereas its glandular substance is supplied by branches from the vagi and the sympathetic nerves.

Development. During the fifth week of foetal life the thymus gland appears as two bilateral diverticula, one on each side, from the ventral ends of the third pharyngenal pouches (Entodermal origin). The two diverticula grow down caudally to lie over the ventral aspect of the pericardium and soon become detatched from their pharyngeal connection and fuse together to form a single lobulated mass. At first the diverticula are hollow outgrowths but soon they become solid by proliferation of the entodermal cells. Irregular outgrowths also appear on the surface to give it a lobulated character which are converted into follicles. Mesenchymal cells from the surrounding soon invade into it and give rise to the formation of the connective tissue elements of the gland. At about the tenth week, lymphocytes appear into the gland and are believed to be formed out of the mesenchymal cells. The entodermal cells are transformed into the reticular elements. The Hassall's corpuscles are believed to be the specialised formation of the reticular cells in which they are the hypertrophied and degenerative product.

Histological structure. The thymus gland is surrounded by a connective tissue capsule which sends in fine septa carrying blood vessels within the gland to subdivide it into innumerable lobules. Each lobule consists of a peripheral denser *cortex* and a central less compact *medulla*.

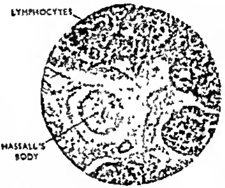


Fig 793. The histological structure of the thymus gland.

Cortex. The cortex consists of closely packed cells of lymphocytes which are usually called *thymic cells* or *thymocytes* and a few reticular cells of epithelial origin which are found to be scattered amongst the lymphocytes. It resembles the cortex of an ordinary lymph node but differs from the latter in having no germinal centre.

Medulla. The medulla consists mostly of reticular cells, a few lymphocytes and the concentric corpuscles of Hassall. The presence of the Hassall's corpuscle forms the characteristic feature of the thymus medulla.

Hassall's corpuscle. It is a cell-nest in which, around one or two centrally placed cells, flattened cells are arranged concentrically so as to give rise to a laminated appearance. The centrally placed cells usually show signs of degeneration. The cells are of epithelial origin and are the specialised formations of the reticular cells formed by transformation of the entodermal cells.

THE SPLEEN

The spleen is the largest ductless gland and lies deeply in the abdominal cavity between the stomach and the diaphragm on the left side. It is dark purple in colour and is extremely friable in consistency. Its shape varies according to the condition of the stomach and the left colic flexure and roughly is of oblong flattened form.

Situation. It is chiefly found in the left hypochondriac region and partly extends into the epigastrium and occupies a recess in between the stomach and the diaphragm. It is obliquely placed and its long axis runs from above downwards, laterally and forwards and practically coincides with that of the tenth rib.

Measurements and weight—

Length	.. 5 inches.
Breadth	.. 3 inches.
Weight	.. 6 ounces.

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Parts for examination. The spleen has got two surfaces—visceral and diaphragmatic, two borders—*superior* and *inferior*, two ends—*lateral* and *medial* and a *hilum*.

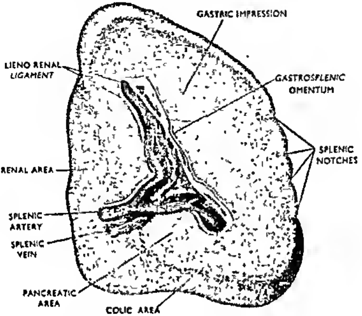


Fig. 794 The visceral surface of the spleen.

The *visceral surface* of the spleen presents the gastric, colic, pancreatic and the renal impressions, and the hilum, which transmits the splenic vessels and nerves. The hollowed out area above and in front of the hilum forms the gastric impression and is in relation with the anterosuperior surface of the stomach from which it is separated by the greater sac. The colic impression is a small depressed area opposite to the lateral end of the spleen and is in relation with the left colic flexure and the phrenico-colic ligament. The pancreatic area is in relation with the tail of the pancreas and intervenes between the gastric and the colic areas. The renal impression lies behind the gastric impression and the hilum and is separated from them by a rounded ridge.

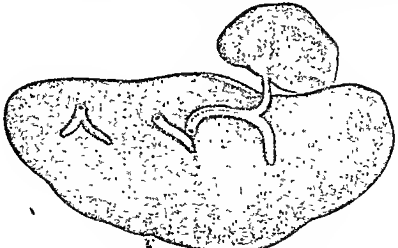


Fig. 795. An abnormal spleen with a splenicula.

The *diaphragmatic* surface is convex and is in relation with the undersurface of the diaphragm which separates it from the ninth, tenth and eleventh ribs and from the lungs, pleura and the costo-diaphragmatic recess on the left side.

The *superior border* of the spleen is thin and presents one or two notches. It separates the gastric impression from the diaphragmatic surface. The *inferior border* is thicker than the superior border and separates the renal impression from the diaphragmatic surface.

The *medial end* of the spleen is rounded and is directed to the vertebral column and corresponds to the level of the 12th thoracic vertebra. The *lateral end* is broad and expanded and lies opposite to the level of the third lumbar vertebra.

Peritoneal relation. The spleen is completely covered by peritoneum except the hilum through which the splenic vessels and nerves enter.

Ligaments of the spleen

(1) *Gastro-splenic ligament.* It is a short fold of peritoneum that connects the fundus of the stomach with the spleen and contains in between its two layers the short gastric and the left gastro-epiploic vessels. Its posterior layer is derived from the *peritoneum of the lesser* sac while its *anterior layer* being derived from the *peritoneum of the greater sac.*

(2) *Lieno-renal ligament.* It is a double fold of peritoneum which forms the true splenic pedicle and carries in between its two layers the splenic vessels and nerves and the tail of the pancreas and connects the spleen with kidney. *Its posterior layer* is derived from the *peritoneum of the greater sac* while its *anterior layer* is derived from the lesser sac.

(3) *Phrenico-colic ligament.* It is a short peritoneal fold that connects the left colic flexure with the diaphragm and supports the lateral end of the spleen and hence it is often called the suspensory ligament of the spleen.

Structure of the spleen. The spleen consists of serous and fibrous coats and a trabecular network containing the splenic pulp, capillary tufts and lymphatic nodules.

Serous coat. It is formed by the peritoneum which entirely covers the spleen except its hilum. It is inseparably connected with the underlying fibrous coat.

Fibrous coat. The fibrous coat is inseparably connected with the serous coat and is known as the *tunica propia.* The tunica propia consists of fibrous tissue together with some elastic fibres embedded in it and some plain muscle fibres. The admixture of elastic fibres and plain muscle fibres makes the tunica propia an elastic and distensible tunic.

Trabecular network. The tunica propia sends out a number of trabecular processes within the organ which further divide into several processes which unite one another and with the fibrous sheath of the vessels and form the trabecular network. Lying within the meshes of the trabecular network is the *splenic pulp* and each network with the contained splenic pulp in its meshes constitutes the *splenic lobule.*

The *splenic pulp* consists of a network of branched connective tissue corpuscle which forms the *sustentacular cells* of the spleen and embedded within it is the *lymphatic nodule* or the *malpighian corpuscle* which stands out as a minute white elevation in contradistinction with the dark red colour of the splenic pulp. The interlobular arteriole breaks up into branches which carry blood to the lymphatic nodule where they form a network of vessels. Capillaries arising from the network pass to the marginal zone of the lobule. The capillary wall is formed by a single layer of endothelial cells which separate from one another to form the splenic sinusoids and consequently the capillary blood comes in direct contact with the reticular tissue of the splenic pulp. The blood of the splenic sinusoid contains a number of white corpuscles and some special cells characteristics of the spleen and are known as the *splenic cells.* Each splenic cell contains a pigment and a red blood corpuscle. From

the splenic sinusoids minute radicle of vein begins which unite together to form a larger vein and the larger veins finally unite together to form the splenic veins which all unite to form the trunk of the splenic vein which joins with the superior mesenteric vein to form the portal vein.

Vascular supply of the spleen. The splenic branch of the coeliac artery supplies the spleen.

The splenic vein joins with the superior mesenteric vein to form the portal vein.

Nerve supply. The spleen is supplied by the splenic plexus derived from the coeliac plexus and receives its fibres from the sympathetics and from the vagus nerve (parasympathetics).

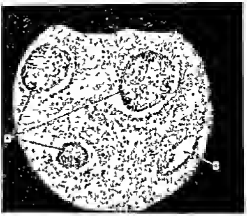


Fig. 796. The histological structure of the spleen.
A=Malpighian corpuscles.
B=Trabeculae.

Lymphatics of the spleen. The lymphatics draining the spleen consist of trabecular and perivascular lymph vessels. The trabecular lymph vessels communicate with the subserous lymphatics and join with the perivascular lymph vessels at the hilum. The perivascular lymph vessels begin in the lymphoid tissue and in the walls of the blood vessels and emerge at the hilum with blood vessels and then join with the trabecular lymph vessels. The collecting trunks end in the splenic lymph nodes, the efferents of which, pass to the coeliac group of lymph nodes.

N.B.—One may be interested to note how the spleen functions as a reservoir of blood and how it is maintaining efficient portal circulation over and above its other functions. The functions of the spleen are as follows:—

(*i*) It is capable of storing large quantities of blood as reserves and is capable of considerable distention owing to large amount of elastic tissues present in its capsule and the trabeculae This reserve blood is thrown out into general circulation, when required, as after a severe haemorrhage or vigorous excercise and hence the size of the spleen is much reduced after haemorrhage.
(*ii*) The spleen undergoes a slow rhythmical contraction, about once per minute, which increases portal pressure and thus helps in the portal circulation.
(*iii*) It produces lymphocytes.
(*iv*) It destroys worn out red blood corpuscles.
(*v*) It forms bile pigments.
(*vi*) It is believed to form antibodies.
(*vii*) It forms R. B Cs during foetal life.

Development. Localised thickenings appear in the coelomic epithelium on the left side of the upper end of the dorsal mesogastrium. The cells of these thickenings invade the underlying mesoderm and form different cell masses which ultimately fuse together and form the lobulated spleen. Later on, this lobulated character disappears but remnants of a few usually persist even in adult life which are represented on its superior border as splenic notches.

THE NERVOUS SYSTEM

The nervous system is a specialised tissue organisation in the body in which the nerve cells with their protoplasmic processes are the constituent units. The protoplasmic processes are drawn out into fine threads which may be either short or long and are known as the nerve fibres. A nerve cell with its processes is called a *neuron*. The neurons are concentrated centrally within the body mostly and form a mass of central body from which fibres (processes) extend peripherally to establish connections with peripherally disposed tissues or structures. This centralization of the nervous system is a vertebrate characteristic. Some of the cells are also grouped peripherally which establish connections both with the peripheral structures as well as with the central body. Thus the nervous system may conveniently be grouped into *central nervous* and *peripheral nervous systems.*

The **central nervous system** or the cerebrospinal axis consists of brain and the medulla spinalis (spinal cord). The nerve cells within the central nervous system are arranged either in groups or in compact layers from which fibres extend variously either for a short or for a long distance within the system and terminate by relays into another group or groups of cells. Thus the nervous pathways within the central nervous system are formed by relays of nerve cells, one group terminates into another by mere contacts. The point of contact between two nerve cells is called a *synapse* (See page. 74).

Functionally the central nervous system is concerned in receiving, co-relating, and integrating incoming nervous impulses so as to give rise to the *motor impulses* for necessary reactions of the body. The brain, in addition, is concerned in the conscious perception of the environment and in unconscious adjustment of the body in relation to the body in space.

The **peripheral nervous system** consists of (*a*) forty-three pairs of cranio-spinal nerves and (*b*) the visceral nervous system. The cranio-spinal nerves consist of 12 pairs of cranial nerves and 31 pairs of spinal nerves. The visceral nervous system is connected with the spinal nerves by grey and white rami communicans and is also connected with some of the cranial nerves.

- Nervous System
  - Central Nervous System
    - Brain
    - Medulla spinalis (spinal cord)
  - Peripheral Nervous System
    - Cranio-spinal nerves
      - Cranial nerves (12 pairs)
      - Spinal nerves (31 pairs)
    - Visceral Nervous System
      - Sympathetic Nervous System
      - Parasympathetic Nervous System

When a neuron is stimulated it becomes excited to react or to give a "response" in the form of an impulse which is conducted away from the cell through its axon to other cell or cells or to the effector organ. Thus excitability by *stimulus, response to stimulus in the form of an impulse* and the *conductivity of the latter away from the cell* are the fundamental characters of a neuron.

Grey and white matter. If we review the development of the nervous system from the neural plate and the neural tube, it will be seen that in the latter, during the earlier days, the cells are found to be scattered at random in which the cells, their dendrons and axons mingle together in a mesh. Subsequently the cell bodies are gathered in groups or *nuclei* and their fibres run into bundles or *tracts*. This organisation of the cells into nuclei and the fibres into tract is governed by the principle of *neurobiotaxis* (nerve-living attraction). The principle of neurobiotaxis postulates that the nerve cells migrate towards the source of stimulation. Thus in the medulla spinalis (spinal cord) the cells are concentrated towards the central canal or centrally. These centrally migrated cells are richly supplied with capillary blood vessels and this mixture of cells and blood vessels gives out a grey appearance on a cross-section and is called the *grey matter*. The long processes of the neurons which run a long way from the parent cell bodies acquire a fatty sheath, the *myelin sheath*, around them which has a high refractive index and it is due to this myelin sheath the mass of fibres gives a white appearance and hence it is called *white matter*.

Nucleus and ganglion. Any localised mass of cells having the same function within the central nervous system is called a *nucleus*. The mass of cells in course of a peripheral nerve is called a *ganglion*.

Somatic and visceral nerves. A nerve is an aggregation of parallel nerve fibres situated peripheral to the central nervous system to which it is connected. A *somatic nerve* is distributed to the structures that develop from the somites and may be either affarent or efferent. The *visceral nerves* supply the viscera and blood vessels and plain muscles and consist of affarent and efferent fibres. The nerves that supply the structures of the branchial arches are known as *special visceral nerves*.

Motor nerves. A motor or efferent nerve takes it origin either from a single nucleus or from a group of nuclei within the central nervous system and terminates into the effector organ either directly or indirectly. In case of voluntary or skeletal and branchial muscles they (motor nerves) terminate into the muscle or muscles (effector organ) directly in the form of motor end-plates. In case of the involuntary muscles and the secreting glands the motor nerves after their origin from the cerebrospinal axis first terminate into the sympathetic ganglion or ganglia (preganglionic fibres) by relays and then the fresh relay fibres from the ganglion or ganglia (postganglionic fibres) pass to the involuntary muscles or to the secreting glands. All motor nerves are made up of *myelinated fibres* and their cells of origin are *multipolar cells*. Thus a motor nerve may be either a somatic motor (supplying skeletal muscle) or efferent, a visceral motor or efferent (supplying either the plain muscles or the secreting glands) or a branchio-motor or special visceral efferent.

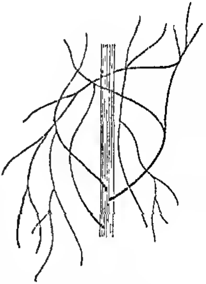


Fig. 797. A peripheral nerve with its branches (Diagrammatic).

Sensory nerves. The sensory nerves are the peripheral processes of the ganglion cells situated outside the central nervous system along the course of a peripheral nerve. They are connected with the central nervous system by the central processes of the ganglion cells constituting the sensory root. A sensory nerve is distributed in a particular area or in a particular structure in which it terminates in a special formation in the form of either a free end or an encapsulated end which are meant for receiving different types of sensations and are known as *receptor organs*. Thus a sensory nerve is ornamented with receptor organs in their fields of distribution

which creates sensory impulse and conduct the same to the central nervous system through the ganglion cells and their sensory root. A sensory nerve may be either *myelinated* or *amyelinated* and its cell body is either bipolar or unipolar cell.

Cranial and Spinal nerves. Although there is no morphological difference between a cranial and a spinal nerve yet there are some fundamental points of differences between them. A cranial nerve may be either entirely motor or seonsory or it may be of mixed type. A spinal nerve is always a mixed nerve. A spinal nerve is attached to the surface of the medulla spinalis (spinal cord) by motor and sensory roots which are separated from each other by a considerable distance (the two roots have two different points of attachments). The motor and sensory roots of a mixed cranial nerve are attached to the same point on the surface of the brain.

Functional types of nerve fibres. Depending on the thickness and the rate of conduction of a nerve fibre, a mixed peripheral nerve may be subdivided into three functional types, **A**, **B** and **C**.

"A"—fibres are the thickest of all and they are most rapidly conducting fibres. They are myelinated and their diameter varies between 20 and 1μ and the rate of conductivity in them ranges from 120 to 6 meters per second. They consist of motor fibres to the striated muscles, and the sensory fibres from the skin and the skeletal muscles.

"B"—fibres are slowly conducting fibres and they consist of myelinated preganglionic autonomic fibres. Their thickness may reach upto a maximum of 4μ in diameter and their conductivity varies between 14 and 3 meters per second.

"C"—fibres are most slowly conducting fibres and they are unmyelinated. The rate of conduction varies between 1·6 meters and 0·3 meters per second.

Theories of Nervous conduction. *Membrane theory.* This theory postulates that a neuron is covered with a film-like polarised membrane having positive and negative electrical charges, the outer surface is charged positively and the inner surface of the membrane is charged negatively. With adequate stimulation it is depolarised at the point of stimulation and subsequently the whole membrane is depolarised with the passage of the impulse. After a lag period (latent period) the membrane regains back its polarity by the cell activity.

The *theory of chemical transmission or the humoral theory.* According to this theory, adrenalin or the acetylcholine, as the case may be, are the chemical agents which are responsible for a nervous conduction. As a proof to this theory it is stated that when a sympathetic postganglionic fibre is stimulated adrenalin is liberated at the nerve terminals, and similarly, when a preganglionic fibre, or a somatic efferent fibre or a postganglionic parasympathetic fibre is stimulated acetylcholine is found to be formed at the terminals of these nerves. The acetylcholine is neutralised by cholinesterase, an enzyme, which is also formed near the nerve terminals.

Ionic Theory. This is the latest theory in which it is postulated that when a nerve is stimulated (during the activity of a neuron) sodium ions permeate into the cell body from the extracellular fluid whereas the potassium ions pass out of the cell due to increased permeability of the cell membrane of the neuron. This passage of the sodium and potassium ions gives rise to an electromotive force which is responsible for the nervous conduction.

THE MEDULLA SPINALIS (SPINAL CORD)

The medulla spinalis is that portion of the central nervous system which is contained within the vertebral canal and is the same prolongation of the brain which is contained within the cranial cavity.

It is about eighteen inches long and half an inch wide and extends from the foramen magnum, where it is continuous with the medulla, to opposite the first

lumbar intervertebral disc (in children the third lumbar spine). It is not of uniform breadth throughout its entire extent but presents two enlargements, cervical and lumbar, and also a tapering extremity, the *conus medullaris*. Surrounding the conus medullaris there are, in series, a number of lower spinal nerves arranged like the tail of a horse and is known as the *cauda equina*.

The enlargements correspond to the area from which the nerves of the limbs arise. The cervical enlargement extends from the margin of the foramen magnum to the level of the second thoracic spinous process and the lumbar enlargement extends from the tenth thoracic to the first lumbar spine.

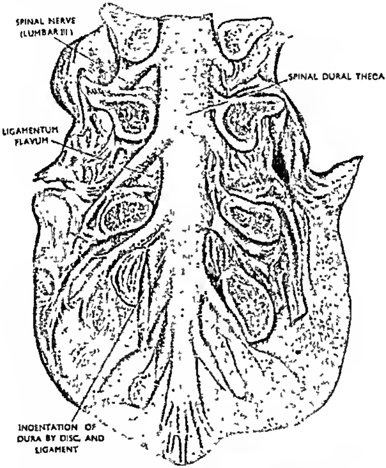


Fig. 798. The caudal portion of the medulla spinalis (spinal cord) with its meninges and nerve roots. With kind permission from Lederle Laboratories Ltd Drawn by Paul Peck.

The spinal meninges. The medulla spinalis is ensheathed by three fibrous membranes, namely, an outer, the dura mater, an intermediate, the arachnoid and an inner, the pia mater; the *dura mater* only loosely surrounds the cord, and is separated from the vertebral canal by the *extradural space* which contains some areolar tissue, the extradural venous plexus and a quantity of fat. The interval between the dura mater and arachnoid mater is called the *sub-dural space* and contains a small amount of lymph. A wider interval, traversed by numerous trabeculae, the sub-arachnoid space, intervenes between the arachnoid mater and the pia mater. It holds cerebrospinal fluid. The *arachnoid mater* is a delicate non-vascular layer and like the dura, it is not firmly attached to the cord. Both the dura and arachnoid with their spaces and contents descend as low as the second sacral vertebra, i.e., both the dura mater

and arachnoid mater together with the sub-arachnoid and the sub-dural spaces extend downwards as far as the level of the second sacral vertebra.

The *pia mater* is closely adherent to the medulla spinalis (spinal cord) and accordingly terminates at the same level with the medulla spinalis i.e., opposite the first lumbar intervertebral disc. From the lower end of the conus medullaris the pia mater prolongs downwards as a delicate thread-like process known as the *filum terminale* which fuses with the periosteum on the back of the coccyx. *The ligamentum denticulatum* are tooth-like processes of pia mater which pierces the arachnoid and connect the pia mater with the dura mater. They run in series on each side of the medulla spinalis and intervene between the two roots of the spinal nerve and partially divide the sub-arachnoid space into two compartments. On the anterior part of the pia mater opposite the median plane there is a thickened glistening line known as the *linea splendens*.

The differences between the spinal and cerebral dura mater:.

Cerebral dura mater	Spinal dura mater
1. Cerebral dura mater consists of two layers, endosteal and meningeal layers, which are closely adherent to each other except at the spaces where they contain the cerebral sinuses. The endosteal layer forms the inner periosteal covering of the cranial bones and the meningeal layer covers the surfaces of the brain.	1. The spinal dura mater consists of a single layer which covers the spinal cord. The vertebral canal has got its separate periosteal lining.
2. The dura mater being intimately adherent to the inner surface of the cranium, there is no extra-dural space.	2. There is always some interval between the periosteal lining of the vertebral canal and spinal dura mater and thus having extra-dural space which contains some loose areolar tissue, venous plexus and some fatty tissue.
3. The cerebral dura mater sends out four processes, falx cerebri, falx cerebelli, tentorium cerebelli, diaphragm sellae, which subdivide the cranial cavity into different compartments.	3. The spinal dura mater does not give any process.
4. The cerebral dura mater is more thick and tough.	4. The spinal dura mater is less thick.

The **vascular supply of the medulla spinalis.** The arteries supplying medulla spinalis are the anterior and posterior spinal arteries from the fourth part of the vertebral arteries and the spinal branches from the posterior intercostal and lumbar arteries.

The *two anterior spinal arteries*, one from each vertebral artery, descend downwards to the level of the olive of the medulla oblongata where they unite together to form a single trunk which descends in front of the medulla spinalis. In its course

downwards it is reinforced by the union of the spinal branches from the second part of the vertebral artery, ascending cervical, posterior intercostal and lumbar arteries. It (the trunk formed by the two anterior spinal arteries) ends below upon the filum terminale. In addition to supplying the pia mater and the nerve roots it furnishes a branch, the anterior median artery, to the anterior median fissure, which on entering the fissure gives off alternately right and left branches called the *commissural arteries*. These are distributed to the corresponding right and left half of the grey matter anteriorly.

The *posterior spinal arteries* pass backwards and then descend as two branches, one in front of and the other behind the posterior roots of the spinal nerves. They are reinfroced by a succession of spinal twigs from the second part of the vertebral artery, ascending cervical, posterior intercostal and lumbar arteries; they supply mainly the white matter and also portions of the grey matter.

The **veins of the medulla spinalis** lie within the pia mater and unite to form an anterior, a posterior and right and left trunks. After being joined by veins

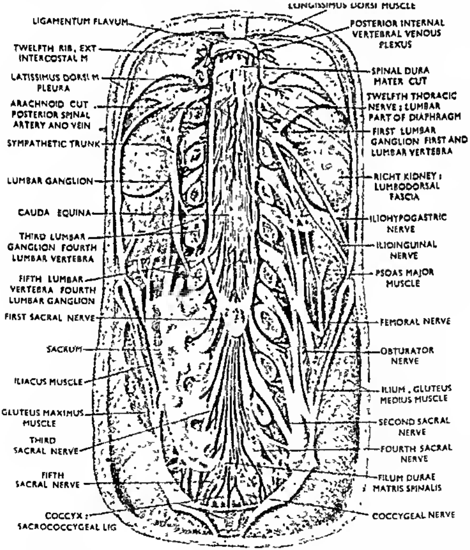


Fig. 799. The lumbar and sacral regions of the medulla spinalis (spinal cord). Seen from behind. With kind permission from Lederle Laboratories Ltd. Drawn by Paul Peck

from the bodies of the vertebrae, branches, emerge through the intervertebral foramina and terminate in the vertebral, intercostal and lumbar veins.

Subdivisions of the medulla spinalis. The medulla spinalis is divided into two symmetrical halves by an *anterior* and a *posterior median fissure*. Each half is further sub-divided into three columns by the attachments of the posterior and anterior nerve roots. The portion lying in between the anterior median fissure and the series of the anterior nerve roots is called the *anterior white column*, the portion in between the anterior and posterior roots is called the *lateral white column* and the portion in between the posterior roots and the posterior median fissure is known as the *posterior white column*. In the cervical and upper thoracic regions the posterior white column is further sub-divided by a shallow longitudinal groove into *fasciculus gracilis* and *fasciculus cuneatus*, the former being medial to the latter.

Section of the medulla spinalis. A transverse section of the spinal cord opposite the mid-dorsal region is seen to consist of a central grey matter and a peripheral white matter.

The central grey matter is divided into two symmetrical halves which are connected to each other by a transverse band of grey matter, the *grey commissure* which is pierced by the *central canal* opposite the median plane; the two symmetrical halves of the grey matter together with the central grey commissure resemble like that of the letter 'H.' The portion of the grey matter lying in front of the transverse band is called the *anterior horn* and the portion posterior to it is known as the *posterior horn* of the medulla spinalis; opposite each end of the transverse band, a conical expansion of the grey matter is known as the *lateral horn* of the spinal cord.

Close to the central region of the medulla spinalis at some places there is no clear cut distinction between grey and white matter and the former is invaded by ascending and descending white fibres and thus the network formed by the interlacing grey and white matter is known as the *reticular formation of the spinal cord*.

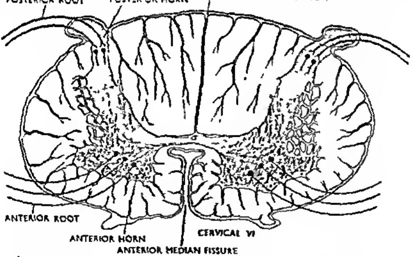


Fig. 800 A transverse section of the medulla spinalis opposite the fourth cervical vertebra.

The *anterior horn*, which is thicker than the posterior horn, is separated from the surface of the spinal cord by a band of fibres known as the anterior white column. It consists of multipolar nerve cells which give rise to somatic efferent fibres which are entirely motor in function and supply the voluntary muscles.

The *posterior horn* is directed backward as elongated grey masses and extends almost upto the surface of the spinal cord. It is composed of nerve cells which give rise to nerve fibres of the second afferent neuron and are entirely sensory in function and receive fibres from posterior root ganglion. Surrounding the posterior horn

there is a mass of gelatinous nervous tissue known as the *substantia gelatinosa.* It consists of both neuroglia cells and nerve cells. Traced upwards the substantia gelatinosa is found to be continuous with the nucleus of the spinal tract of the trigeminal nerve.

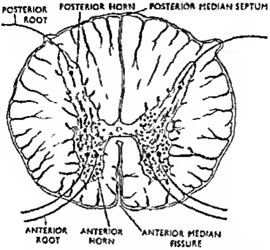


Fig. 801 A transverse section of the medulla spinalis (spinal cord) opposite the seventh thoracic vertebra.

The *lateral horn* is composed of nerve cells which give rise to visceral efferent fibres which pass through the anterior root fibres and constitute the preganglionic sympathetic fibres.

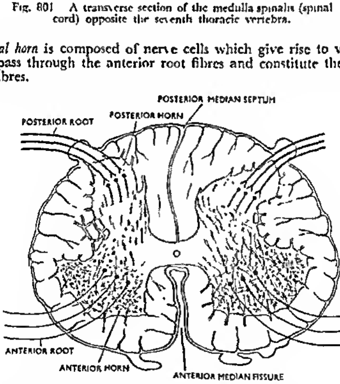


Fig. 802. A transverse section of the medulla spinalis opposite the third lumbar vertebra.

The *central canal* of the medulla spinalis exists throughout its whole length and is continuous above with the inferior angle of the fourth ventricle and below it extends far down as two inches within the filum terminale. It is surrounded by a gelatinous

This is chiefly concerned with the maintenance of postural tone of the voluntary muscles.

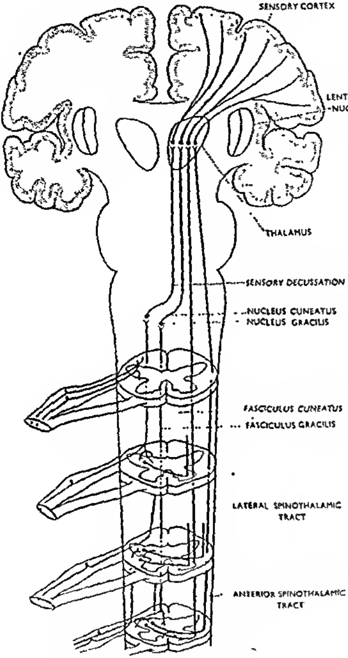


Fig. 803. The anterior spinothalamic tract.

(3) **Tecto-spinal tract.** This is the efferent pathway for the superior quadrigeminal body and together with the spino-tectal tract completes the visual reflex arc. It arises from the cells of the superior quadrigeminal body and soon decussates with the fellow of its opposite side and then passing through pons and medulla runs through the anterior white column of the spinal cord and finally ends in the anterior horn cells of the same side.

(4) **Vestibulo-spinal tract.** This tract is the efferent pathway for equilibratory reflexes from the vestibular nucleus. Its fibres arise from the lateral vestibular nucleus in the pons and medulla and descend through the spinal cord in the anterior white column and finally end in the anterior horn cells of the same side.

Development of medulla spinalis. The medulla spinalis develops from that portion of the neural tube which lies below the level of the fourth somite. In the cord region the neural tube at first presents a pair of thick lateral walls, a thin roof and a floor and a narrow cleft-like lumen. Each of the thick lateral walls differentiates into outer marginal layer, inner ependymal layer and intermediate mantle zone. Later on, the ventral half of each lateral wall becomes thickened due to proliferation of the

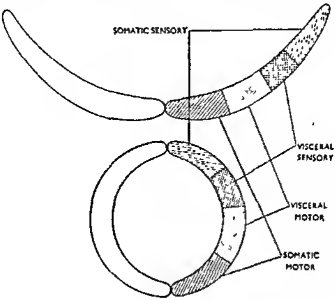


Fig. 804 The developing medulla spinalis (spinal cord) with the sensory and motor zones.

cells of the mantle zone. As a result of this differential growth the ventral part of the lumen of the cord becomes compressed and a furrow known as the *sulcus limitans* appears on each side which separates the thicker ventral part from the comparatively thinner dorsal part of the lateral wall. This thickened ventral part of each lateral wall is now called the *basal lamina*. The dorsal portion also becomes thicker and is called the *alar lamina* and the two laminae are separated from each other by the sulcus limitans.

The basal laminae of the neural tube form that part of the medulla spinalis which is essentially motor in function while the alar laminae develop into parts which are sensory in function. With further growth and increase in size of the laminae the central canal is progressively diminished in size and later on it is completely obliterated posteriorly by fusion of its two walls and the fused walls form the posterior median septum. Concurrently with the formations of the posterior median septum the basal lamina of each side projects forwards and consequently a groove appears between the two developing basal laminae which later on forms the anterior median fissure. The ventral part of the original lumen of the central canal persists as definitive central canal.

With the rapidly differentiating cells in the medulla spinalis increasing number of ascending and descending fibres develop and differentiate later on into anterior, lateral and posterior white columns.

In post-somite embryos, and until the beginning of the third month, the developing medulla spinalis extends into the developing coccygeal region. Later on, the vertebral column, which develops in the mesoderm surrounding the cord, grows more rapidly and as a result of this differential growth between the spinal cord and the vertebral column the former lies at the level of the third lumbar vertebra at or after birth. Consequent upon the disproportion in the rate of growth, the spinal

nerves below the upper cervical region pass out with increasing degree of obliquity and with the retrogression of the spinal cord the lower part of the vertebral canal is only occupied by the lower spinal nerves (cauda equina) and the filum terminale.

THE BRAIN OR THE ENCEPHALON

Brain or encephalon is that portion of the central nervous system which is contained within the cranial cavity, and is surrounded by three membranes, the dura mater, arachnoid mater and the pia mater in order from without inwards.

Man is superior to animal because he stands erect on his legs and uses them for locomotive purposes, and that the superior extremity is an added gift and above all the well-developed central nervous system which he possesses is his highest valuable possession which functions in various ways. Taking the human body as a great living factory, the brain is the main generator in it, the nerves are its wiring mechanism and other organs and body parts are its accessories.

The central nervous system in man is divisible into two parts, brain and medulla spinalis. The brain is its bulkiest portion which is contained within the cranial cavity and the medulla spinalis is its downward prolongation which is contained within the vertebral canal and extends as far as the upper border of the second lumbar vertebra.

During earlier months of development the outer surface of brain presents a smooth surface but later on localised depressions appear on it which subsequently form distinct fissures or sulci and are responsible for the convoluted character of its surfaces.

Structurally it consists of an outer grey matter and an inner white matter; the grey matter is composed of nerve cells while the white matter is composed of nerve fibres.

Brain or Encephalon

- Prosencephalon or Fore brain
  - Telencephalon
  - Diencephalon
  - Rhinencephalon
- Mesencephalon or Mid brain
  - Ventral portion (cerebral peduncles)
  - Dorsal portion or Tectum (corpora quadrigemina)
- Rhombencephalon or Hind brain
  - Ventral portion (pons and medulla oblongata)
  - Dorsal portion (cerebellum)

Coverings of the brain or the cerebral meninges. Brain or encephalon is covered by three membranes and they, from without inwards, are the dura mater, arachnoid mater and the pia mater. The dura mater is the toughest and thickest of all and is derived from the mesoblastic tissue whereas the arachnoid mater and the pia mater are epiblastic in origin and are thin and delicate membranes.

Dura mater. It forms the outermost covering of the brain and is thick and tough. It consists of two layers: (*a*) outer endosteal and (*b*) the inner meningeal layers. These two layers are firmly adherent to each other everywhere except at

places where they enclose cerebral venous sinuses. The sinuses are enclosed either by separation of these two layers or by reduplication of its inner or meningeal layer.

Outer endosteal layer. It forms the periosteum of the inner surface of the cranial bones and ends below at the margins of the foramen magnum. It is firmly adherent to the bones at the basal area and less so in the region of the vault of the skull except opposite the sutures where it is firmly adherent and is connected with the epicranium by the sutural ligament.

The inner or meningeal layer of the dura mater invests the surfaces of the brain and sends out the following processes:

(1) *Falx cerebri.* It is a sickle-shaped fold of the inner layer of the dura mater which dips in between the two cerebral hemispheres. It is formed by the reduplications of the meningeal layer. Anteriorly it is attached to the crista gali and the frontal crest of the frontal bone and superiorly it is attached to the margins of the superior sagittal sulcus and posteriorly it is attached to the superior surface of the tentorium cerebelli, inferiorly it ends in a free concave border. The superior sagittal sinus lies along its upper border, the inferior sagittal sinus along its free, concave, lower border and the straight sinus lies along its line of attachment with the tentorium cerebelli.

(2) *Tentorium cerebelli.* It forms a tent-like investment for the cerebellum and intervenes between it and the occipital lobe of the cerebral hemisphere. Its outer convex border is attached to the margins of the transverse sulcus of the occipital bone, the mastoid angle of the parietal bone and the superior border of the petrous part of the temporal bone and finally it ends by being attached to the posterior clinoid processes. Its inner border is concave and free; anteriorly the inner border ends by being attached to the anterior clinoid processes. In between the concave free margins there is an oval space, the door of the tent, which gives passage to the mid-brain. It encloses two sinuses, (*a*) the transverse sinus lies at the posterior part of its attached border and (*b*) the superior petrosal sinus lies along its line of attachment on the superior border of the petrous part of the temporal bone.

(3) *Falx cerebelli.* It is a small sickle-shaped process of dura mater which intervenes between the two halves of the cerebellum posteriorly. It contains the occipital sinus.

(4) *Diaphragm sellae.* It is a short process of dura mater which roofs in the pituitary fossa. It is pierced by the infundibulum. It contains the two intercavernous sinuses.

The meningeal layer of the cerebral dura mater is continuous with the spinal dura mater around the margins of the foramen magnum.

The arachnoid. The arachnoid is the delicate vascular membrane that lines the brain and bridges across the lips of the sulci and fissures of the brain and intervenes between the dura mater and the pia mater. It is continuous below with the spinal arachnoid and ends below opposite the second sacral vertebra. The following are the processes given out by the cerebral arachnoid.

1. *Arachnoidal villi.* These are delicate tortuous processes given out by the arachnoid mater which push the dura mater in front of them and eventually pierce them and project into the lumen of the cerebral sinuses. The arachnoidal villi are covered by a specialised mesothelial cells by means of which the cerebrospinal fluid is conveyed to the blood of the cerebral sinuses.

2. *Arachnoidal granulations* (Pacchionian bodies). These are the masses of aggregated arachnoidal villi which project into the lumen of the cerebral sinuses and may cause protrusion of the wall of the venous sinus against the cranial wall in the region of the sinus and cause pits, the granular foveolae (pits), on the inner surface of the cranium near the sulci for the cerebral sinuses.

N.B.—The mesothelial cells cover the arachnoidal villi and Cushing termed these cells as "Meningocytes" which are found in the different parts of the central nervous system and they function in a variety of ways for the defence of the body.

They are usually found in the following places:

(a) Arachnoidal villi.
(b) Within the fibrous structure of the dura mater.
(c) On the arachnoid mater covering of the posterior root ganglion of the spinal nerve.
(d) In the arachnoid mater covering the choroid plexus of the lateral ventricle.
(e) In the cerebrospinal fluid.

Functions—

(i) They act as scavengers and engulf foreign bodies, bacteria, etc., and hence they act as phagocytes.
(ii) They help in the reparation of the dural rent.
(iii) They excrete cerebrospinal fluid to the venous sinuses and thereby maintain equilibrium of pressure between the two systems.
(iv) They absorb colouring matter.
(v) They have the power to produce bile pigment from the haemoglobin (producer of bile pigments).

Pia mater. It forms the delicate vascular membrane which closely invests the surfaces of the brain and dips into the bottom of the fissures and sulci. Below it is continuous with the pia mater covering of the medulla spinalis and ends opposite the level of the second lumbar vertebra and then is continued as the filum terminale. The space between it and the arachnoid is the sub-arachnoid space which contains the cerebrospinal fluid. The following processes are given out by the pia mater:

(a) *Perivascular processes.* The arteries supplying the brain lie in the sub-arachnoid space and they receive first an investment from the arachnoid and when they pass to the brain substance by piercing the pia mater they receive another investment from the pia mater and the potential space in between its double sleeves is known as the perivascular space.
(b) *Processes dipping into the sulci and fissures.*
(c) It provides *sheaths for the cranial and spinal nerves.*
(d) It forms *tela chorioidea of the third and the fourth ventricles.*
(e) *In the medulla spinalis it sends out a septum that dips into the anterior* median fissure of the medulla spinalis. It presents a thickening opposite the septum within the anterior median fissure of the medulla spinalis and is known as the *linea splendens.*
(f) *Ligamentum denticulata.* They are the tooth-like processes of pia mater that project outwards in between the anterior and posterior roots of the spinal nerves and after piercing the arachnoid they are attached to the dura mater. They are about 21 in number on each side and serve to suspend the spinal cord in the mid-line.

The sub-arachnoid cisternæ. These are sub-arachnoid spaces on the different surfaces of the brain (especially on the basal surface), formed by the process of reflection of the arachnoid mater on the surface of the brain. The pia mater of the brain intimately covers the surfaces of the brain and dips into the sulci so as to cover their bottom and then is reflected on to the adjacent gyri but the arachnoid mater on the other hand bridges across the inequalities on the surfaces of the brain, that is, from one gyrus to another (not dipping into the sulcus between the gyri) or from one part of the brain to another and thus leaving wide gaps or spaces at certain places between the arachnoid mater and pia mater known as *sub-arachnoid cisternæ.* These spaces (sub-arachnoid cisternae) are usually more capa-

cious and wide at the basal area of the brain because here the inequalities mark their prominence. According to situations the following sub-arachnoid cisternae may be distinguished.

1. Cisterna cerebellomedullaris.
2. Cisterna pontis.
4. Cisterna interpeduncularis.
4. Cisterna of the lateral sulcus.
5. Cisterna venae magnae cerebri.

1. *Cisterna cerebellomedullaris.* It is formed by the arachnoid mater bridging the interval between the medulla oblongata and the undersurface of the cerebellum. Below it is continuous with the sub-arachnoid space of the medulla spinalis (spinal cord).

2. *Cisterna pontis.* It is present on the ventral aspect of the pons and it contains the basilar artery.

3. *Cisterna interpeduncularis.* It is situated at the interpeduncular fossa at the base of the brain and contains the circulus arteriosus and the roots of the oculomotor nerve.

4. *Cisterna of the lateral sulcus.* It is formed by the arachnoid mater bridging across the lips of the lateral sulcus and contains the middle cerebral artery.

5. *Cisterna venae magnae cerebri.* It occupies the interval between the splenium of the corpus callosum and the superior surface of the cerebellum. It contains the great cerebral vein.

The sub-arachnoid cisternae contain the cerebrospinal fluid and directly or indirectly communicate with one another and with the cavity of the fourth ventricle by the apertures on the roof of the fourth ventricle.

The circulation of the cerebrospinal fluid. The fluid is secreted by the ependymal cells covering the choroid plexuses of the lateral and, to a certain extent, by that of the fourth and third ventricles. Leaving the lateral ventricles by the interventricular foramen the cerebrospinal fluid traverses through the third ventricle. From there it reaches the fourth ventricle via the aqueduct of the mid-brain. Emerging through the central and lateral apertures in the pia mater forming the roof of the fourth ventricle, the fluid enters the cerebello-medullary cistern and descends in the sub-arachnoid space down the back of the spinal cord as far as the second sacral spinous process. Ascending on the front of the cord the fluid occupies the pontine and interpeduncular cisterns respectively and is then distributed along the lines of the main cerebral arteries. From the interpeduncular cistern the fluid ascends on the lateral surface of the corresponding cerebral hemisphere through the gap in the tentorium cerebelli and reaches the arachnoid villi associated with the superior sagittal sinus and is able to pass back again into the blood-stream.

Within the vertebral canal there is no active flow of the cerebro-spinal fluid whereas within the cranial cavity there is active flow which is subject to different variations according to the change of pressure between the two fluids (blood of the cerebral sinuses and the cerebrospinal fluid).

Artery supply of the brain. The arteries supplying the brain are the cerebral portions of the internal carotid artery, and the basilar artery formed by the union of the two vertebral arteries.

Circulus arteriosus (circle of Willis). The circulus arteriosus is a remarkable arterial anastomosis, situated in the cisterna interpeduncularis at the base of the brain. It forms a circular outline, hence called the circulus arteriosus, which encircles almost all the structures in the interpeduncular fossa. The formation of the anastomosing circle is described as follows:

In front, the two anterior cerebral arteries are joined to each other by the anterior communicating artery; behind, the basilar artery (formed by the union of

the two vertebral arteries) divides into the posterior cerebral arteries, each of which is connected with the internal carotid artery of the same side by the *posterior communicating* artery.

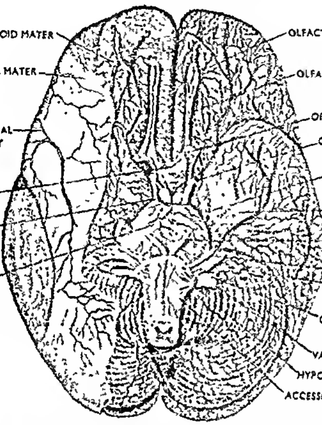


Fig. 805. The basal region of the brain. With kind permission from Lederle Laboratories Ltd. Drawn by Mr. Paul Peck.

The circulus arteriosus forms the chief source of artery supply to the brain as follows:

The brain gets its blood supply from the circulus arteriosus formed by middle, anterior and posterior cerebral and the anterior and the posterior communicating arteries. The branches supplying the brain are arranged themselves in two groups, central and cortical. The central and the cortical group of blood vessels form two different systems which are independent of each other and they never communicate with each other in any part of their intracerebral course.

The *central system of blood vessels* are strictly 'end arteries', i.e., each artery that penetrates into the brain supplies its own territory and nerve anastomoses with any other artery. They arise from the circulus arteriosus and are arranged into six groups, anteromedial, posteromedial, right and left anterolateral and right and left posterolateral groups. They supply the thalami and the corpora striata. The anteromedial group arises from the anterior cerebral and the anterior communicating arteries, the posteromedial group arising from the posterior cerebral and the posterior communicating arteries, the right and the left anterolateral group from the middle cerebral while the right and the left posterolateral groups arise from the posterior cerebral arteries.

The *cortical system of vessels* form the terminal branches of the anterior, middle and the posterior cerebral arteries and they divide into long and short branches.

The long branches penetrate through the outer grey matter to reach the subjacent white matter and are about one and a half inches long. The short branches ramify in the pial sheath and supply the superficial cortical grey matter.

N.B. The cereberal artery, once it penetrates into the brain, never communicates with any other artery and occlusion of such an artery has grave consequences in that, the part of brain supplied by it, is cut off from its blood supply and there is softening of the particular area. The border zones between the territories of brain supplied by the long and the short branches of the cortical system of blood vessels and between the central and cortical systems of blood vessel are poor in blood supply and consequently softening of brain is common in these places.

The veins of the brain. The veins of the brain differ from other veins in that they are devoid of any muscular wall and they have no valves. They have a fibrous wall which is lined by endothelium. They have an important bearing in that before reaching the sinuses of the dura mater, into which they open, they are to traverse the sub-arachnoid space and consequently are subjected to presure of the cerebrospinal fluid.

The *cerebral veins* are divided into superficial and deep group of veins. The superficial cerebral veins come under four heads, superior, middle, inferior and the anterior cerebral. The deep group of veins include the internal cerebral, thalamostriate, choroid, inferior striate, great cerebral and basal veins.

The *cerebellar veins* are the superior and inferior cerebellar veins. The superior cerebellar vein opens into the great cerebral vein while the inferior cerebellar veins open into the occipital, sigmoid and inferior petrosal sinuses.

Lymphatics of the brain. The brain is devoid of any lymph vessels but they are replaced by spaces surrounding the cerebral arteries and are known as *perivascular spaces.* The cerebral arteries are contained within the sub-arachnoid spaces and as they reach these spaces they receive a sheath from the arachnoid mater and finally when they pierce the substance of the brain, they receive another investment from the pia mater. Thus a cerebral artery, as it passes through the brain substance, is enveloped by two sleeves, one from the arachnoid mater and another from pia mater and the potential space between the two sleeves is called the perivascular space. The tissue fluid of the brain and cord passes through these perivascular spaces and finally passes into the cerebrospinal fluid.

THE HIND BRAIN OR THE RHOMBENCEPHALON

The hind brain or the rhombencephalon is divisible into ventral and dorsal parts. The ventral part consists of medulla oblongata and the pons while its dorsal part is formed by the cerebellum.

Medulla oblongata. The medulla oblongata forms the direct continuation from the lower part of the pons and is continuous with the medulla spinalis (spinal cord) below. It extends from the lower margin of the pons to a transverse plane passing above the first pair of cervical nerves.

It is piriform in shape and measures about 3 cm. in length, 2 cm. transversely and 1·25 cm. antero-posteriorly. Its anterior and posterior surfaces are marked by median fissures, the anterior and posterior median fissures.

Anterior median fissure. It extends along the entire length of the medulla oblongata. Below it is continuous with the anterior median fissure of the medulla spinalis. Above it ends in a small triangular recess immediately below the pons, known as the foramen caecum. Its lower part is interrupted by a band of fibres which crosses obliquely from one side to the other and constitute the *decussation of pyramid.*

Posterior median fissure. It is present only at the lower part of the medulla. Below it is continuous with the similar fissure of the medulla spinalis and above it ends at the upper angle of the fourth ventricle.

Thus we see that the anterior and posterior median fissures divide the medulla into two halves which are continuous below with the corresponding half of the medulla spinalis. Each half of the medulla presents another two vertical fissures on its lateral aspect and according to the situations they are called the antero-lateral and postero-lateral fissures. The roots of the hypoglossal nerve emerge from the antero-lateral fissure; the roots of the glossopharyngeal, vagus, and accessory nerves, make their exit through the postero-lateral fissure.

The pyramid or the anterior region of the medulla oblongata. The anterior region of each half of the medulla is called the *pyramid* and lies in between the anterior median and the antero-lateral fissures. It is separated from the pons by a transverse fissure which gives exit to the abducent nerve. It is separated from the olive by the antero-lateral fissure which transmits the roots of the hypoglossal nerve. It forms an elevation which is wider above and gradually narrows as it approaches the medulla spinalis. The ventral aspect of each pyramid is crossed by the anterior external arcuate fibres as they run upwards, backwards and laterally from the anterior median fissure to join the restiform body or the inferior cerebellar peduncle.

The two pyramids, one on each side, are placed side by side being separated from each other by the anterior median fissure. They contain the pyramidal tract fibres or the cerebrospinal fibres which reach them from the basilar part of the pons. In the lower part of the medulla the pyramidal fibres of the two pyramids undergo partial decussation opposite the anterior median fissure forming the *great decussation of pyramid*. The decussated fibres form the crossed pyramidal tract which pass to the opposite lateral white column of the spinal cord. About one-fourth of the fibres which occupy the lateral aspect of the pyramid do not decussate but they form the uncrossed or direct pyramidal tract fibres and pass to the anterior white column of the medulla spinalis on the same side.

The lateral region of the medulla. The lateral or intermediate region of the medulla lies in between the antero-lateral and postero-lateral fissures. Its upper part forms a prominent oval mass known as the *olive* and is produced by the underlying olivary nucleus. The roots of the hypoglossal nerve emerge in front of *the olive while those of the glossopharyngeal, vagus and the accessory nerves emerge* behind it. Above it is separated from the pons by a deep transverse fissure and inferiorly it is crossed by the anterior external arcuate fibres. Above and lateral to the olive the roots of the facial and stato-acoustic (auditory) nerves make their appearance from the transverse groove at the lower border of the pons, the stato-acoustic (auditory) nerve being placed lateral to the facial nerve and in between the two there lies the sensory root of the facial nerve.

Below the olive the lateral area is seen to be confluent with the lateral column of the medulla spinalis and contains the anterior and the posterior spino-cerebellar tracts.

The posterior region of the medulla. It lies in between the posterolateral fissure in front and the posterior median fissure behind. It is divided into medial and lateral areas by a shallow groove. The medial part consists of the fasciculus gracilis while the lateral part forms the fasciculus cuneatus of the medulla spinalis. The swelling of the fasciculus gracilis is named as the gracile tubercle and is produced by the nucleus gracilis. The swelling of the fasciculus cuneatus is termed the cuneate tubercle and is caused by the cuneate nucleus.

The upper part of the posterior region of the medulla oblongata is occupied by the inferior cerebellar peduncle situated in between the lower part of the fourth ventricle and the roots of the glossopharyngeal and vagus nerves.

THE FOURTH VENTRICLE

The fourth ventricle or the cavity of the hind brain is a rhomboidal or a diamond-shaped cavity situated behind the lower part of the pons and the upper

part of the medulla oblongata. As it is diamond-shaped it presents four angles, superior, inferior and two lateral. Besides the four angles it consists of a floor, two lateral walls and a roof.

The *superior angle* is continuous with the aqueduct of the mid-brain and the *inferior angle* with central canal of the lower part of the medulla spinalis. Its *lateral angles* are prolonged into small recesses round the dorsal and lateral aspects of the inferior cerebellar peduncle and are known as the lateral recesses.

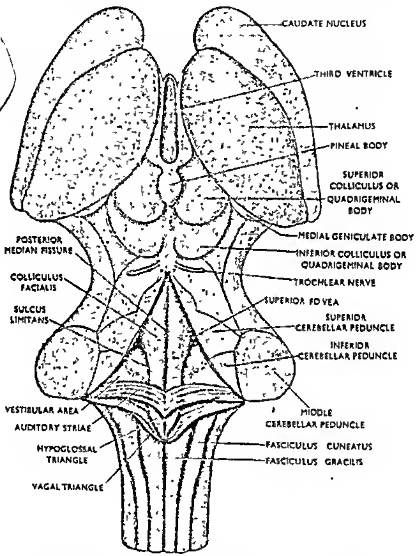


Fig. 806. The diencephalon with the caudate nucleus, the mid-brain and the hind brain without the cerebellum. Seen from behind.

The floor of the fourth ventricle. The floor or the anterior wall of the fourth ventricle is formed by the dorsal surfaces of the pons and medulla oblongata. It is rhomboidal in shape, that is, it resembles two triangles resting on their bases. Of its four angles, two are lateral and make the widest part of the floor; of the other angles, the superior is placed on a level with the upper border of the pons and is continuous with the aqueduct of the mid-brain and the inferior one is on a level with the lower border of the olive and is continuous with the central canal of the

medulla spinalis. At the lateral angles the space is prolonged for a short distance between the cerebellum and the medulla and thus forms the lateral recesses. Here the ependyma has slit-like apertures on each side, the lateral apertures, which communicate with the sub-arachnoid space.

The floor of the fourth ventricle is divided into two symmetrical halves by a median sulcus which extends from the superior to the inferior angle. On each side of the median sulcus there is an eminence, the *medial eminence*, lateral to which there is a sulcus, the *sulcus limitans*. Opposite the maximum breadth of the floor the medial emience forms a swelling, the *colliculus facialis*, caused by the abducent nerve nucleus and the ascending portion of the facial nerve. Below, the medial eminence forms a triangular area, the *hypoglossal triangle* which consists of hypoglossal nucleus and the nucleus intercalatus. The upper part of the sulcus limitans is covered by a layer of pigmented nerve cell and presents a bluish-grey area called the *locus caeruleus*; opposite the colliculus facialis it forms a depression, the *superior fovea*, and opposite the hypoglossal triangle it forms another depression, the *inferior fovea*. Lateral to the superior and inferior fovea there is an elevated area, the *vestibular area*. Crossing the vestibular area and the medial eminence there are a number of white strands and these are termed the *auditory striae*. Below the inferior fovea and between the hypoglossal triangle and the lower part of the vestibular area, there is a triangular dark field known as the *vagal triangle* caused by the dorsal nucleus of the vagus nerve.

The lateral walls of the fourth ventricle. The lateral boundaries of the lower half of the fourth ventricle are formed from below upwards by the gracile and cuneate tubercles and the inferior cerebellar peduncles. Above, the lateral boundary is completed by the superior cerebellar peduncles.

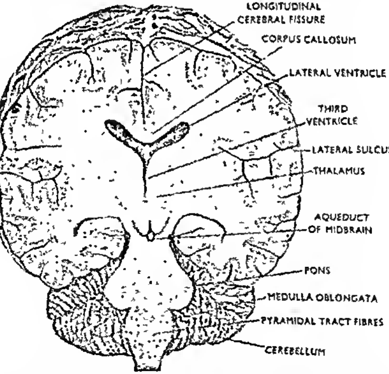


Fig. 807. A coronal section of the brain showing the pyramidal tract. With kind permission from Lederle Laboratories Ltd. Drawn by Mr. Pual Peck.

The roof of the fourth ventricle. The upper part of the roof is formed by the superior cerebellar peduncles and superior medullary velum. The lower portion is formed by the posterior part of the upper surface of the ... ior

medullary velum, the ventricular ependyma with tela chorioidea, taeniae of the fourth ventricle and the obex.

The *openings in the roof of the fourth ventricle.* In the roof of the fourth ventricle there are three openings,—a median and two lateral. The median aperture is always constant and is of considerable size. It is situated below the nodule. The lateral apertures are present at the ends of the lateral recesses and they are partly occupied by the choroid plexus which protrudes into the sub-arachnoid space. It is through these apertures on the roof of the fourth ventricle that the cerebrospinal fluid of the fourth ventricle circulates into the sub-arachnoid spaces.

Transverse section of the medulla oblongata opposite the lower, closed part of the medulla. The following features will be noticed in the above section:

(*a*) *Decussation of the pyramid.* The pyramidal fibres reaching the lower part of the pyramid cross each other and pass to the opposite lateral white column of the spinal cord In their course they pass through the anterior horn cells and thus split the anterior horn cell from the central grey core.

(*b*) Posteriorly the posterior horn cells form two rounded collections of grey matter forming the *nucleus gracilis* and *nucleus cuneatus*, and into these nuclei the upward continuation of the fasciculus gracilis and cuneatus will be seen to enter.

(*c*) Close to the surface and ventri-lateral to fasciculus cuneatus is the *nucleus of the spinal tract of the trigeminal nerve.*

(*d*) Lying in close contact with the lateral aspect of the nucleus of the spinal tract is the *spinal tract of the trigeminal nerve* which lies just beneath the surface and forms an important landmark in this situation.

(*e*) The area between the nucleus of the spinal tract with its tract fibres and the pyramid there lies the *rubro-spinal tract*, the *spino-cerebellar tract* and the *spinal lemniscus.* The anterior and the posterior spino-cerebellar tracts lie close to the surface being placed one before the other The spinal lemniscus lies ventri-medial to the posterior spino-cerebellar tract.

Transverse section through the upper part of the closed portion of the medulla oblongata.

(*a*) Lying behind the pyramids and intervening between them and the central canal is the *great sensory decussations* in which the fasciculus gracilis et cuneatus of one side cross with the fellow of its opposite side after their relay in the nucleus gracilis et cuneatus.

(*b*) Lying behind the central grey matter is the more prominent *nucleus gracilis et cuneatus.*

(*c*) The *internal arcuate fibres* arise from the ventral part of the nucleus gracilis et cuneatus and pass forwards to join in the sensory decussations.

(*d*) The *nucleus of the spinal tract* with its tract lies ventri-lateral to the fasciculus cuneatus.

(*e*) The *rubro-spinal tract*, the *spinal tract*, the *spino-cerebellar* tract and the *spinal lemniscus* all occupy a position situated between the sensory decussations and the lateral aspect of the medulla oblongata and due to compactness of fibres the precise position of these tracts are ill-defined.

IV ventricle

Transverse section through the lower part of the floor of the medulla oblongata (upper-half of the medulla oblongata).

(*a*) Anteriorly on either side of the median plane is the *pyramid* traversed by the pyramidal fibres.

(*b*) Dorsi-lateral to the pyramid is the *olivary nucleus* which is a hollow nucleus with crenated margins.

(*c*) *Olivo-cerebellar tract*, which arises from the medial side of the olivary nucleus, crosses with the fellow of its opposite side at the median plane and passes to the opposite inferior cerebellar peduncle.

(*d*) Extending from before backwards on either side of the median plane is the *medial lemniscus* which is the upward prolongation of the fibres of the sensory decussation.

(e) Opposite the hypoglossal triangle is the *hypoglossal nucleus* and lying behind the hypoglossal nucleus and obscrued by the medial lemniscus is the *medial longitudinal bundle*.

(f) Dorsi-lateral to the hypoglossal nucleus are the *nucleus intercalatus* and the *dorsal nucleus of the vagus nerve*.

(g) Between the anterior end of the medial lemniscus and the dorsal nucleus of the vagus nerve is the *nucleus of the tractus solitarius*.

(h) The *nucleus ambiguus* is situated within the deep part of the reticular formation and is placed mid-way between its anterior and posterior aspects away from the median plane.

(i) The *fibres of the inferior cerebellar peduncle* occupy the extreme dorsi-lateral angle of the section and the spinal tract of the trigeminal nerve with its nucleus lies ventral to it.

(j) The *posterior spino-cerebellar tract*, as it passes to the inferior cerebellar peduncle, intervenes between it and the spinal tract of the trigeminal close to the surface of the medulla.

(k) Ventral to the spinal tract of the trigeminal is the *anterior spino-cerebellar tract*.

(l) Ventri-medial to the spinal tract of the trigeminal are the *spinal lemniscus* and the *rubro-spinal tract*.

THE PONS

The pons is that portion of the hind brain that lies in front of the cerebellum and intervenes between the cerebral peduncles above and the medulla oblongata below. Inferiorly it is separated from the medulla oblongata by a transverse sulcus both in front and laterally, and the abducent, facial and the stato-acoustic (auditory) nerve emerge from this sulcus from before backwards.

It is divisible into *ventral* and *dorsal parts*; the anterior surface of the ventral part or the basilar part is convex from side to side as well as from above downwards and lies in contact with the dorsum sellae of the sphenoid and the basilar part of the occipital bone. Its dorsal part forms posteriorly the upper part of the floor of the fourth ventricle and is overlapped on either side by the superior carebellar peduncles. Above, the pons is continuous with the cerebral peduncles whereas below, it is continuous with the medulla oblongata.

Opposite the median plane the basilar part presents a shallow vertical groove known as the sulcus basilaris and lodges the basilar artery; on either side of the sulcus basilaris there is a low rounded elevation caused by the descending fibres of the cerebro-spinal nerves; on either side of this elevation the roots of the trigeminal nerve emerge, the smaller motor root being placed in front of the larger sensory root. The portion of the pons lying posterior to the trigeminal roots constitutes its dorsal part.

Internal structures of the pons. A section through the pons reveals that it is composed of scattered masses of grey cells which constitute different nerve nuclei and transverse and longitudinal bands of fibres which constitute different nerve tracts. To ease complications the nerve nuclei and nerve tracts found in the pons have been summated as follows:

Basilar part of the pons. The basilar part of the pons consists of scattered cell-masses with nerve fibres, the cell-massess constitute the nuclei pontis and the fibres form the cerebro-spinal (pyramidal) and cerebro-pontine fibres.

The cerebro-spinal fibres descend downwards to the pyramid of the medulla oblongata for their subsequent course to the medulla spinalis.

The cerebro-pontine fibres which have their origin from the different parts of the cerebrum, are relayed to the nuclei pontis at different levels. Fresh fibres arise from the nuclei pontis and passing transversely across the pons they reach the opposite cerebellum through the middle cerebellar peduncle.

Lower tegmental or dorsal part of the pons. The lower tegmental region of the pons constitutes the *formatio reticularis* of the pons. It is so named because here

there is no central grey core and instead the grey matter is broken into isolated cell masses by interlacing fibres and it resembles a network of grey and white matter. The broken cell masses form the *superior, inferior, lateral* and *medial vestibular nuclei*, the *central* and *dorsal cochlear nuclei*, the *nuclei of the abducent* and *facial nerves*, the *superior salivary nucleus*, the *central and dorsal nuclei of the corpus trapezoideum* and the *nucleus of the spinal tract of the trigeminal nerve.*

The vestibular nerve nuclei receive the central processes of the bipolar cells of the vestibular division of the stato-acoustic (auditory) nerve and cerebellopontine fibres from the cerebellum. Fresh fibres arise from the vestibular nuclei which form (1) the medial longitudinal bundle, (2) a part of the corpus trapezoideum, (3) the vestibulo-spinal tract and (4) the vestibulo-cerebellar tract.

(1) Through the median longitudinal bundle the vestibular division of the stato-acoustic (auditory) nerve sends its fibres to the nuclei of the third, fourth, sixth and eleventh cranial nerves.

(2) Corpus trapezoideum is the bundle of transversely disposed fibres derived partly from the vestibular and partly from the cochlear nerve nuclei. A few fibres of the corpus trapezoideum are relayed to the nucleus of the corpus trapezoideum by means of which the vestibular fibres are conveyed to the nuclei of the other cranial nerves. The majority of the fibres of the corpus trapezoideum ascend upwards as the lateral lemniscus which end in the medial geniculate body and the inferior quadrigeminal body and from there relay fibres associate the vestibular and cochlear fibres with the temporal lobe of the brain.

(3) The vestibulo-spinal fibres from the vestibulo-spinal tract end in the anterior horn cells of the spinal cord.

(4) The fibres of the vestibulo-cerebellar tract associate the vestibular fibres with the cerebellum.

The nerve nuclei for the sixth and seventh nerves give origin to the respective nerves. The superior salivary nucleus gives origin to fibres which join the facial nerve and leave it as the chorda tympani branch which carries, in addition to the taste fibres for the anterior two-thirds of the tongue, secreto-motor fibres to the submandibular and sublingual salivary glands.

Upper tegmental part of the pons. The upper tegmental region of the pons has the special features of having superior sensory nucleus and the motor nucleus of the trigeminal nerves and in addition to the trigeminal lemniscus which arises from the sensory nuclei of the trigeminal nerve, it contains the spinal lemniscus, the medial lemniscus and the anterior spino-cerebellar tract.

THE CEREBELLUM

The cerebellum is the largest sub-division of the hind brain which lies within the posterior cranial fossa and is hidden from view by the tentorium cerebelli which separates it from the posterior part of the cerebral hemispheres. It is oval in form and is broader transversely than antero-posteriorly. It weighs about 150 grms. In the adult, and bears a ratio of 1 : 8 with the cerebrum (cerebellum 1 and cerebrum 8) in weight.

Like the cerebrum, the cerebellum is composed of grey and white matter and the arrangement of the two substances are also similar to that of the cerebrum, that is, the grey matter or cortex lies externally and the white matter or the medulla lies internally. The cortex of the cerebellum is thrown into numerous slender folds known as the *folia* which are separated from each other by shallower fissures. The folia form the characteristic feature of the cerebellum as to its identity. The medulla or the white matter occupies its interior, and when sectioned it resembles a branching tree in appearance. *Thus the folia and the characteristic medulla resembling a branching tree (arbor vitae cerebelli) form the special feature of identity of the cerebellum.* Embedded within the medulla are found isolated masses of grey matter which form its different nuclei.

Parts for examination—Anatomical. The cerebellum consists of two lateral portions known as the *cerebellar hemispheres* and a median portion known as the *vermis* which connects the two cerebellar hemispheres together in the median plane. The surfaces of the cerebellum are *superior* and *inferior*. The vermis on the superior surface is called the *superior vermis* while that on the inferior surface is called the *inferior vermis*. The inferior vermis lies in a deep furrow on the inferior surface between the two hemispheres known as the *vallecula*. At the extremities of the vermis, the cerebellar hemispheres are separated from each other by deep notches. The anterior notch is V-shaped and is known as the *incisura semilunaris* which embraces the superior cerebellar peduncles and the inferior quadrigeminal bodies. The posterior notch is narrow and is occupied by a process of dura mater known as the *falx cerebelli*.

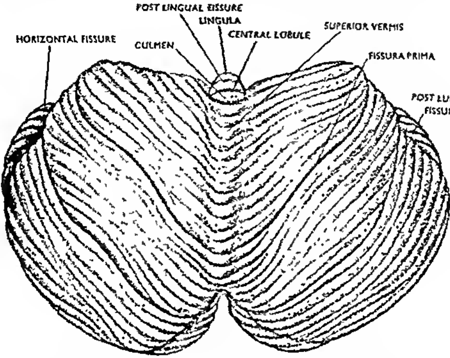


Fig. 808. The superior surface of the cerebellum. Seen from above

Lobes and fissures. Both the cerebellar hemispheres and the vermis differ in their mode of sub-divisions on the two surfaces of the cerebellum while the *great horizontal* fissure which is of considerable depth, extends round the circumstance of each cerebellar hemisphere. In dealing with lobes and fissures, the vermis and the cerebellar hemispheres have heen dealt separately in relation to the surface of the cerebellum.

Superior vermis. It is the foliated median elevation, the monticulus, which connects the two cerebullar hemispheres on the superior surface of the cerebellum. On either side the superior vermis slopes down to be continuous with the cerebellar hemisphere and that there is no sharp demarcation between it and the latter.

It extends between the incisura semilunaris (anterior notch) and the posterior notch and its most prominent portion is known as the *culmen monticuli*. The *fissura prima* cuts the superior vermis a little behind the culmen monticuli and extends into the hemisphere towards the horizontal fissure. A little behind the fissura prima, the *post-clival fissure* cuts the superior vermis and then extends into the hemisphere like the fissure prima. The segment of the superior vermis between the fissura prima and the post-clival fissure is called the *clivus*. The posterior extremity of the superior vermis that lies dorsal to the post-clival fissure is called the *folium vermis*. The ventral portion of the anterior extremity of the superior vermis

which overlies the superior medullary velum immediately below the inferior quadrigeminal bodies is called the *lingula* while its dorsal portion which occupies the angle of the incisura semilunaris is called the *central lobule*. The lingula is separated from the central lobule by a short horizontal fissure the *precentral fissure*. Dorsal to the central lobule is the culmen from which it is separated by another short fissure called the

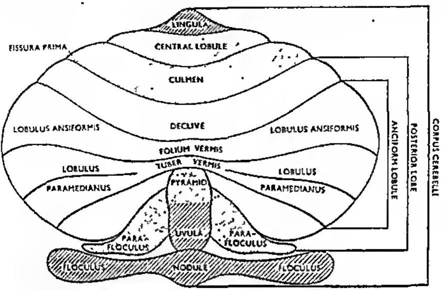


Fig 809. The subdivisions of the cerebellum as seen from the superior surface.

post-central fissure. Both the precentral and the postcentral fissures are limited only to the breadth of the superior vermis. To summarise it may be mentioned that four fissures namely *precentral, postcentral, fissure prima* and the *postclival fissure* subdivide the superior vermis into *lingula, central lobule, culmen monticuli*, the *clivus monticuli (Lobules clivi) and the folium vermis.*

Cerebellar hemisphere. Superior surface. The subdivisions of the superior surface of each hemisphere are in conformity with the subdivisions of the superior vermis. Each subdivision of the superior vermis, except the lingula, extends on either side and demarcates an area on the superior surface of the hemisphere which constitutes a lobe or a lobule. In order from before backwards these subdivisions are, *alae, anterior and posterior lunate lobules* and the *ansiform lobules* (upper part).

The lateral extention of the central lobule of the superior vermis forms *ala of the central lobule* on each side. The extension from the culmen is the *anterior lunate lobule* which lies in front of the fissura prima. The *posterior lunate lobule* is the lateral extension of clivus and lies in between the fissura prima and the post-clival fissure. The lateral extension of folium vermis is the *ansiform lobule* (upper part) and lies between the post-clival fissure and the horizontal fissure.

Inferior vermis. It is the median foliated elevation on the inferior surface of the cerebellum and occupies the floor of the vallecula. The inferior vermis is demarcated from the cerebellar hemisphere by a narrow para-vermian gutter known as the *sulcus valleculae*.

The anterior part of the inferior vermis is called the *nodule* and consists several small folia. It forms the part of the roof of the fourth ventricle and is connected laterally with the flocculus with a sheet of white fibres known as the inferior medullary velum and forms the stalk of the flocculus. Behind the nodule and separated by a narrow fissure called the *postnodular fissure*, is the *uvula*. It is triangular in form the apex of which is directed towards the nodule. Behind the uvula is the conical *pyramid* demarcated by a deep fissure. Behind the pyramid and separated from it by a deep

fissure, the *suprapyramidal fissure* or the *fissura secunda* is the posterior extremity of the inferior vermis which forms the *tuber vermis* or the *lobulus tuberis*. The suprapyramidal fissure is the morphological demarcation between the middle and the posterior lobes. To summarise it may be said that the inferior vermis is divided into *nodule, uvula pyramid* and the *lobulus tuberis* in order from before backwards.

Cerebellar hemisphere. Inferior surface. The subdivisions of this surface of the hemisphere is not regular in conformity with the subdivisions of the inferior vermis as is found with the superior vermis and the superior surface of the cerebellum. Most of this surface of the hemisphere is formed by the lower part of the *ansiform lobule*, a small part by the *tonsillar lobe* (Torsil), the *floccule* and the *parafloccule*.

Extending from the nodule of the inferior vermis laterally and connected by a stalk, the inferior medullary velum, is the *floccule* which is a small foliated lobule which lies close to the anterior margin of the cerebellum immediately below the middle cerebellar peduncle. The two flocculi together with the nodule of the inferior vermis constitute the *flocculo-nodular lobe,* which is the oldest part morphologically. On either side of the uvula but not continuous with it is a small foliated oval mass known as the *tonsil* or the *paramedian lobule.* The latter is separated from the uvula by the sulcus valleculi and from the rest of the inferior surface which forms the lower part of the *ansiform lobule* by a deep fissure known as the *retrotonsillar fissure.* Closely attached to the postero-lateral aspect of the flocculus is a very small lobule known as the *paraflocculus* which usually forms a vestigial structure in man but it becomes very much well developed in aquatic animals.

Before going to deal with the morphology of the cerebellum the anatomical lobes and fissures are summarised as below:

Cerebellum (subdivisions)

- Vermis
  - Superior vermis
    - Lingula
    - Central lobule
    - Culmen
    - Vermis *folium or lobulus folii*
  - Inferior vermis
    - Nodule
    - Uvula
    - Pyramid
    - Lobulus tuberi
- Hemisphere
  - Superior surface
    - (1) ala
    - (2) Anterior lunate lobule
    - (3) Posterior lunate lobule
    - (4) Ansiform lobule (upper part)
  - Lower surface
    - (1) Tonsil
    - (2) Flocculus
    - (3) Ansiform lobule

Fissures

- Horizontal fissure
- Superior surface
  - (1) *Precentral*
  - (2) *Postcentral*
  - (3) *Fissura prima*
  - (4) *Postclival fissure*
- Lower surface
  - (1) *Postnodular fissure*
  - (2) *Fissure between uvula and pyramid*
  - (3) Suprapyramidal fissure or fissura secunda
  - (4) Retrotonsillar fissure

Morphology and development of the cerebellum. The cerebellum develops from two cerebellar rudiments, one on each side, derived from the proliferation of the cells of the mantle zone of the alar lamina from its dorsal edge.

The terminal nucleus of the vestibular nerve is in close relation with these rudiments and it may be seen that they (the primary rudiment) appear as an extension of the vestibular nerve nucleus and therefore the developing cerebellum is brought

primarily into the functional concern of equilibration. The cerebellar rudiment first appear during the second month of foetal life and grow rapidly due to excessive proliferation of the cells of the mantle zone and some of the cells from the median plane in the roof plate connecting the two rudiments, and thus a cord of cells grows in the roof plate which connects the two cerebellar rudiments together. The cerebellar rudiments together with the connecting cord of cells become dumble-shaped and acquire a *horizontal position dorsally due to accentuation of the pontine flexure.* During the third month of intrauterine life they bulge out considerably and give rise to the formation of the hemispheres. With further growth, the cerebellum gradually develops into its adult form due to its acquiring newer connections from the developing medulla spinalis and the brain.

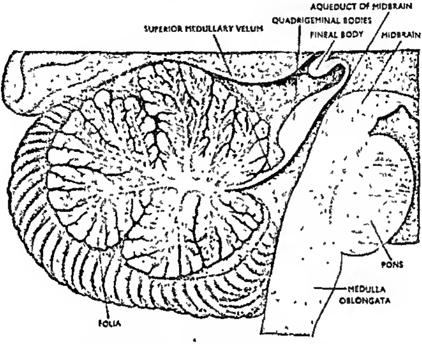


Fig. 810. A mid-sagittal section through the hind brain and mid-brain.

As the primary cerebellar nodules are the extension of the vestibular nucleus so the first stage of development is the formation of the "vestibular cerebellum" in which equilibration becomes the main concern and it consists of a median portion with two lateral bulgings. The lateral bulging is the *flocculus*. Subsequently with the developments of the limb muscles it becomes necessary to bring them under cerebellar control, and therefore, the spinocerebellar tracts appear which invade into the developing cerebellum carrying proprioceptive impulses from the muscles to the latter. Thus the cerebellum becomes competent to discharge regulatory influences in maintaining postural tone of the muscles in response to proprioceptive impulses from them. With the invasion of the spinocerebellar tract a new functional unit is formed within the cerebellum which may be called the "spinal cerebellum". The spinal cerebellum appears in the middle of the older vestibular cerebellum and divides the latter into a small anterior median part, the *lingula*, a posterior median part, the *nodule*, and two lateral portions, the *flocculi* on the each side. Posterolateral to the flocculus the rudimentary lateral expansion of the spinal cerebellum forms the *paraflocculus*. Later on, with the increased domination by the cerebral cortex, the cerebellum is also brought under its control by cerebro-pontine, ponto-cerebellar fibres which invade into the middle of the vestibulo-spinal cerebellum and give rise to the formation of the *lobus medius* in the cerebellum. The lobus medius consists

The post-calcarine sulcus lies in the medial surface and begins from the occipital pole from where it descends downwards to join with the parieto-occipital

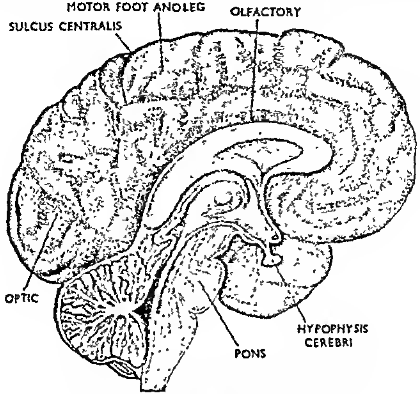


Fig. 817. A mid-sagittal section of the brain.

sulcus and then runs forwards and downwards into the inferior surface. The portion of the brain lying in between the calcarine and parieto-occipital sulci constitutes

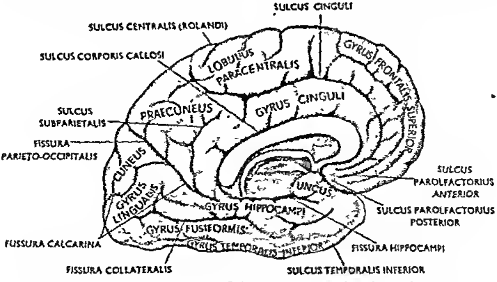


Fig. 818. A mid-sagittal section of the cerebrum showing the sulci and gyri on the medial surface.

the *cuneus* of the occipital lobe and that below the calcarine sulcus is known as the *lingual gyrus*.

The anterior part of the medial surface is divided into an outer zone and an inner zone by means of a curved sulcus, the sulcus cinguli. The outer zone is divided

into larger anterior part which forms the medial frontal gyrus and a smaller posterior part which forms the paracentral lobule, by means of a vertical sulcus which ascends upwards from the sulcus singuli opposite the middle of the corpus callosum to the superomedial margin. The inner zone forms an arched gyrus, the gyrus singuli, which passes around the corpus callosum. The portion of the brain lying in between the upturned end of the sulcus singuli and parieto-occipital sulcus is called the pre-cuneus.

The sulci and gyri on the inferior surface. The inferior surface is divided into orbital and tentorial surfaces. The *orbital surface* close to the medial border presents an antero-posterior sulcus known as the olfactory sulcus which contains the olfactory bulb and tract. The short strip of cortex lying on the medial side of this sulcus is known as the gyrus rectus. The remaining portion of the orbital surface is divided into four orbital gyri (lateral, medial, anterior, posterior) by means of a H-shaped sulcus.

The *tentorial surface* is divided into hippocampal gyrus, and lateral and medial occipito-temporal gyri by means of collateral sulcus and occipito-temporal sulcus. The collateral sulcus runs forwards from the occipital pole parallel to the calcarine sulcus and on its medial side there lies the hippocampal gyrus. The occipito-temporal sulcus lies on the lateral side of the collateral sulcus and the corresponding occipito-temporal gyrus lies on either side of it.

The anterior portion of the hippocampal gyrus is curved on itself to form a globular swelling known as the *uncus*. It is separated from the temporal pole by means of a sulcus known as the *rhinal sulcus* which is often continuous with the anterior end of the collateral sulcus.

THE FUNCTIONAL AREAS ON THE SURFACE OF THE BRAIN

Precentral area. It includes the precentral gyrus and the posterior portions of the superior, middle and inferior frontal gyri. It is divided into two parts, larger anterior and smaller posterior parts, by passing a line through the precentral gyrus. The smaller posterior part gives rise to the pyramidal fibres and are concerned in the volitional movement of muscles and this is grouped in this area from above downwards as lower limb, trunk, upper limb, mouth, lips, tongue and larynx. The larger anterior part governs the actions of the posterior part and actual act of a particular movement is performed by this area. As for example the flexion of the forearm requires the movement of more than one muscle and these different muscles are put into action in one time so as to cause the movement of flexion.

Frontal area. The rest of the frontal lobe beyond the precentral area is known as the frontal area or the silent area of the brain. This area is connected with visual, auditory, and sensory areas by means of different association fibres. It is also connected with the thalamus by itinerant fibres. Functionally it analyses different afferent impulses and controls the power of judgement, distinction between sorrows and pleasure, judgment between right and wrong, power of concentration, power of attention and power of intelligence.

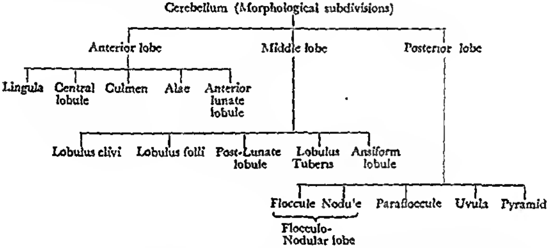
Post-central area. This area is included in the lower part of the post-central gyrus and is continued over the supero-medial margin into the adjoining part of the paracentral lobule. It is divided into two parts, anterior and posterior. The anterior part receives the afferent impulses from the different parts of the body whereas the posterior part stores up the experiences of older objects as in cases of senses of steriognosis.

Visual area. It consists of visuo-sensory area and visuo-psychic area. The visuo-sensory area is embedded in the walls of the calcarine sulcus and extends on to the surface of the cuneus above and the lingual gyrus below. It is the receiving centre for all kinds of visual impressions including the form, size, shape, colour, motion, illumination and transparency.

of a central portion, the *vermis* and two lateral expansions, one on each side. Each lateral expansion is further subdivided into a larger *ansiform lobule* and a smaller *tonsillar* or paramedian lobule.

With the appearance of the lobus medius the developing cerebellum is naturally subdivided into anterior, middle and posterior lobes. The fissure between the anterior and the middle lobes is first to appear and hence it is called the *fissura prima* or the *primary fissure*. Other fissures appear later with further development. The *suprapyramidal fissure* forms the demarcation between the middle and the posterior lobes.

Thus morphologically the cerebellum may be divided into *anterior*, *middle* and *posterior lobes*. The anterior lobe lies in front of the fissura prima and includes *lingula, central lobule, culmen monticuli, alae,* and *anterior lunate lobule*. The middle lobe lies behind the fissura prima and consists of *lobulus clivi* or *clivus monticuli, lobulus folii* or the *folium vermis, posterior lunate lobule*, the *ansiform lobule* and the *tuber vermis* or the *lobulus tuberis*. The rest of the cerebellum is formed by the posterior lobe and is separated from the middle lobe by the suprapyramidal fissure. It includes the *flocculo-nodular lobe, paraflocculus,* the *uvula* and the *pyramid*. Given below in a tabular form are the morphological subdivisions of the cerebellum:



The cerebellar nuclei. There are four deeply placed nuclear masses within the white matter of each cerebellar hemisphere namely the *dentate nucleus*, the *nucleus emboliformis*, the *nucleus globosus* and the *nucleus fastigii* or the roof nuclei.

The *dentate nucleus* is the largest of all and is embedded in the midst of the white matter of each hemisphere. It resembles the olivary nucleus of the medulla oblongata and consists of corrugated lamina of grey matter which is folded to encapsulate a mass of white matter having a hilum or opening on its supero-medial side so as to give exit to the white matter which forms the dentato-rubrothalamic fibres and emerge out through the superior cerebellar peduncle.

The *nucleus emboliformis* forms a small lamina of grey matter which lies close to the medial aspect of the hilum of the dentate nucleus.

The *nucleus globosus* lies medial to the emboliformis nucleus at a deeper horizontal plane.

The *nucleus fastigii* is also called the *roof nucleus*. It lies within the vermis close to the median plane and therefore each nucleus is very closely related to the fellow of its opposite side. It gives rise to fibres which form the fastigio-bulbar tract, a small efferent pathway from the cerebellum. The fastigio-bulbar tract emerges out through the restiform body and ends mostly in the formatio reticularis of the pons and medulla and partly in the vestibular nuclei.

Thus it appears that the cerebellar nuclei are embedded in the white matter of each hemisphere in a definite order and their arrangement, in order from lateral

to medial side, is dentate nucleus, nucleus emboliformis, nucleus globosus and the nucleus fastigii.

Phylogenitically, that is, if we trace back the evolutionary history of the cerebellum it is found that the first part of the organ to develop, in the animal series, is the vestibular cerebellum or archicerebellum which is mainly concerned with equilibration. With further progress in the evolution, the subject, whose muscular system requires more control than simple equilibration for co-ordinated movement, is endowed with the paleocerebellum or the muscle-joint-tendon cerebellum or the spinal cerebellum. With the development of the cerebrum the neocerebellum develops for endowing the muscular system of the body with the cerebro-cerebellar influences which offer newer qualities to the muscular system so that they can adapt themselves *for skilled, discriminative* and *labile activity.* With gradual progression, the growth of evolutionary older parts of the cerebellum becomes suppressed by the over-growth of the newer parts, thus the paleocerebellum is larger than the archicerebellum while the neocerebellum is the largest of all.

Thus **phylogenitically** the cerebellum can be divided into archicerebellum, paleocerebellum and the neocerebellum.

The archicerebellum. The archicerebellum or the vestibular cerebellum is the smallest unit of the cerebellum and consists of nodule, flocculi, uvula and lingula.

Connections. It receives *afferent fibres* from the vestibular nerve of the same side mostly and a few only from the opposite side. The vestibular fibres reach it both directly as well as indirectly by relay fibres through superior and lateral (Deiters) vestibular nuclei. The cerebellar nucleus in connection with the archicerebellum is the fastigial nucleus. The *efferent fibres* from the archicerebellum pass mostly to the fastigial nucleus, the relay fibres from which, form the *fastigio-bulbar tract* which also receives some fibres directly from the archicerebellum. The fibres from the fastigio-bulbar tract pass partly through the superior and partly through inferior cerebellar peduncles to the vestibular nuclei and reticular formation. Thus it becomes apparent that the archicerebellum forms a part of a circuit through which the impulses from the vestibular nerve nuclei are mediated, possibly with modifications, to the fastigial nucleus and then back to the vestibular nuclei.

The paleocerebellum. The paleocerebellum or the muscle-joint-tendon cerebellum or the spinal cerebellum is larger than the archicerebellum but smaller than the neocerebellum. It occupies mostly the rostral two-thirds of the dorsal surface and consists of lingula, lobus centralis, ala, culmen, declive, quadrangular lobule, and the uvula and the pyramid on the ventral aspect.

Connections. It receives *afferent fibres* from the spinal cord (through dorsal and ventral spino-cerebellar tracts), extrapyramidal system and basal ganglia (through olive), lateral reticular nucleus and the arcuate nucleus and from the dorsal funiculus-arcuate-fibres system. Except the dorsal spino-cerebellar tract which enters into it through the superior cerebellar peduncle all the other fibres enter into it through the inferior cerebellar peduncle.

The *efferent fibres* from the paleocerebellum after being mediated through the dentate nucleus and the globose and emboliform nuclei constitute the great efferent pathway from the cerebellum which passes through the superior cerebellar peduncle (brachium conjunctivum) to the mid-brain in the red nucleus. From the latter, fibres form the rubro-spinal tract which relays in the medulla spinalis.

The neocerebellum. The neocerebellum or the "cerebro" cerebellum develops in association with the cerebrum. This is the largest of the three functional regions of the cerebellum and forms about 2/3rds of it. It extends from the posterior quadrangular lobes to the tonsil.

Connections. It receives *afferent fibres* from almost all parts of the cerebral cortex. The two descending tracts from the cerebrum, the fronto-ponto-cerebellar and temporoponto-cerebellar tracts descend through the cerebral peduncle and lie on either

e of the pyramidal tract, the fronto-ponto-cerebellar tract lying on the medial side d end by relaying on the nuclei pontis. Relay fibres from there pass through the rachium pontis) middle cerebellar peduncle to the neocerebellar cortex.

Fig. 811. The appearance of a Purkingi's cell of the cerebellum.

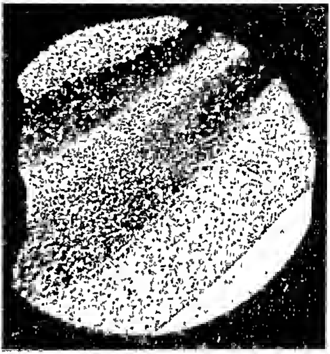


Fig. 812 The low power view of the cerebellum. (Microphotograph).

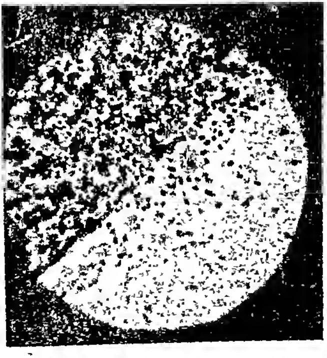


Fig. 813. The high power view of the cerebellum. (Microphotograph).

The neocerebellar discharges pass through its *efferent fibres* which negotiates t to the cerebellar nuclei, mainly the dentate nucleus, and relay fibres from there

pass through the superior cerebellar peduncle and terminate by relays mainly to the ventrolateral nucleus of the thalamus and partly to the red nucleus and reticular formation. Some of these fibres may even pass to the medulla spinalis. Relay fibres from the thalamus spread to the motor region of the cerebral cortex (Areas 4 and 6).

Thus it appears that the cerebrum negotiates its plan of action to the cerebellum through corona radiata, internal capsule, cerebral peduncle, nucleus pontis, and middle cerebellar peduncle, and the cerebellum keeping in touch with the vestibule and the medulla spinalis reviews the plan, utilises its wisdom about its own part of the responsibility in the execution of the plan and then sends it back to the cerebrum via dentate nucleus, superior cerebellar peduncle, thalamus, internal capsule and corona-radiata.

Functions of the cerebellum. The functions of the cerebellum are known from various conditions of disorders of the organ. All signs and symptoms due to disorders of the cerebellum are manifested by the disorder of the motor system and can be grouped under two main headings namely, *ataxia* and *asynergia*. Ataxia means inability to localise the body parts in space correctly or loss of sense of position of the body whereas asynergia means inability to make muscles work together either in groups or in sequences. As it is universally accepted that no sensory consciousness resides in the cerebellum, the condition of ataxia, through a manifestation of the cerebellar lesion, may be attributable to the involvement of some common pathway to cerebellum and other conscious centres (thalamus and cerebrum).

The manifestations under the heading "asynergia" are the following:

(*a*) Atonia—meaning loss of tone of the muscles.
(*b*) Asthenia—denotes weakness of muscular actions with a tendency to rapid fatigue.
(*c*) Adiadokinesis or dysdiadokinesis—inability to perform supination and pronation in proper sequence.

THE MID-BRAIN

The mid-brain is the shortest segment of the brain measuring about 2 cm. in length. It connects the sub-thalamic region and the cerebral hemispheres with the pons and the cerebellum.

It consists of a ventral portion and a dorsal portion, separated from each other in its interior by the aqueduct of the mid-brain. The ventral portion comprises of the cerebral peduncles while the dorsal portion consists of the quadrigeminal bodies or in other word, the tectum.

The cerebral peduncles. The cerebral peduncles are two in number, each arising upwards and laterally from the upper surface of the pons on each side of the median plane. As they pass upwards, they diverge from each other so as to enclose a space between them, the interpeduncular fossa. A thin band of white substances, the taenia pontis, winds round each peduncle close to its attachment with the pons and then enters the cerebellum between the middle and superior cerebellar peduncles.

The ventral surface of each cerebral peduncle is crossed from medial to lateral side by the superior cerebellar and posterior cerebral arteries. Anteriorly close to its disappearance into the cerebral hemispheres it is embranced by the optic tract from before backwards. The medial surface of each peduncle presents a furrow, the medial sulcus, through which the oculomotor nerve emerges. Its lateral surface also presents a furrow, the lateral sulcus, through which the fibres of the lateral lemniscus come out to pass into the inferior quadrigeminal body and the inferior brachium.

In a transverse section through the peduncle it is found to contain a semilunar-shaped pigmented area, the substantia nigra, which divides each peduncle into a ventral part and a dorsal part. The ventral part is known as the *base* of the cerebral peduncle while the dorsal part as the *tegmentum*.

The **base of the cerebral peduucle** contains only the white fibres, consisting of cerebro-spinal and cerebro-pontine fibres.

The **tegmentum** is composed of a reticulum of longitudinal and transverse fibres and a considerable number of nerve cells. The nerve cells in the central part are aggregated together to form red nucleus while those around the aqueduct give origin to the third and fourth cranial nerves. Lying lateral to these is the upper

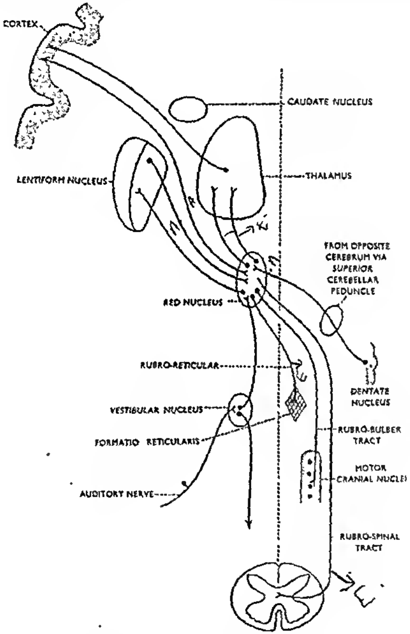


Fig. 814. The connections of the red nucleus.

nucleus of the fifth cranial nerve. The chief groups of fibres are (1) superior cerebellar peduncles, (2) medial lemniscus, (3) lateral lemniscus, (4) tecto-spinal tract, (5) medial longitudinal fasciculus, (6) mesencephalic root of the fifth nerve, and (8) pallido-rubro-olivary tract. For connections of the red nucleus see the accompanying diagram.

The **tectum or the quadrigeminal bodies.** The tectum or the quadrigeminal bodies occupy the posterior part of the mid-brain and consist of four rounded

eminences, separated from each other by a cruciform sulcus. They are placed above the superior medullary velum and below the third ventricle and the posterior commissure. They are overhung by the splenium of the corpus callosum and to a small extent by the pulvinar of the thalamus.

The vertical limb of the cruciform sulcus expands above to form a dimple into which the pineal body rests and its lower end forms a ridge-like elevation, the frenulum, on either side of which the trochlear nerve emerges.

Of the four eminences the upper pair is called the *superior quadrigeminal bodies* and the lower, the *inferior quadrigeminal bodies.* Extending upwards and laterally from the lateral side of each quadrigeminal body there is an elevated white band known as the *brachium.* The *superior brachium* extends from the superior quadrigeminal body to the lateral geniculate body; and the *inferior brachium* extends from the inferior quadrigeminal body to the medial geniculate body.

The *superior brachium* conducts the optic tract fibres from the lateral geniculate body to the superior quadrigeminal body and the *inferior brachium* carries the auditory fibres from the inferior quadrigeminal body to the medial geniculate body.

In structure the superior corpora quadrigemina consists of several layers of grey and white matter. The inferior quadrigeminal body consists of a central grey core with a white cortex. In function the superior pair serves as reflex centre for sight and the inferior ones as reflex centre for hearing.

The aqueduct of the mid-brain. The aqueduct of the mid-brain is the tubular passage connecting the third and the fourth ventricles. Its roof is formed by the quadrigeminal bodies and its floor and side walls are formed by the dorsal aspect of the cerebral peduncles. Internally it is lined by columnar ciliated epithelium, outside which is a thick layer of grey matter—the stratum gresium—continuous with the grey matter of the fourth ventricle. The oculomotor, trochlear, and part of the trigeminal nerves arise from this grey matter.

The geniculate bodies. The geniculate bodies are two in number—a medial and a lateral on each side.

The *medial geniculate body* forms an oval elevation situated on the lateral side of the superior corpora quadrigemina and is overhung by the pulvinar of the thalamus. It is connected with the inferior quadrigeminal body by the inferior brachium through which it receives the auditory fibres. Relay fibres from this pass to the temporal lobe of the brain. *The lateral geniculate body* forms a low rounded eminence on the inferolateral aspect of the posterior end of the thalamus. It is connected with the superior quadrigeminal body by the superior brachium through which it sends out the optic tract fibres to it; the lateral geniculate body receives the majority of the optic tract fibres and gives rise to relay fibres which finally pass through the internal capsule to the cuneus of the occipital lobe.

THE DIENCEPHALON

The diencephalon is that portion of the central nervous system which intervenes between the cerebral hemispheres (telencephalon) above and the mid-brain (mesencephalon) below. It consists of thalamus, epithalamus, metathalamus and hypothalamus.

Thalamus. Thalami are two large, oval, convex cell-masses situated below the cerebral hemispheres and above the cerebral peduncles. They are obliquely placed in such a way that their anterior ends converge together whereas their posterior ends diverge from each other and as they diverge posteriorly they enclose a space between them known as the third ventricle.

Each thalamus consists of anterior and posterior ends and four surfaces, namely superior, inferior, lateral and medial.

The *superior surface* slopes from above downwards and medially and is overlapped laterally by the caudate nucleus from which it is separated by the stria semicircularis, a narrow white band of fibres between the two and the thalamostriate vein. The rest of the superior surface is divided into a lateral and a medial area by a curved groove which lodges the posterior column of fornix. The lateral portion forms a part of the floor of the lateral ventricle whereas its medial portion is in relation with the tela chorioidea and the choroid plexus of the third ventricle. Its *medial surface* forms the lateral boundary of the third ventricle and is connected with the fellow of its opposite side by a band of fibres known as the connexus interthalamicus. The

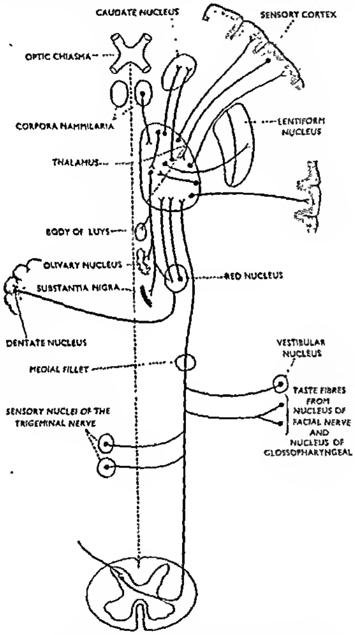


Fig. 815. The fibre-tract of the medial lemniscus or fillet.

medial surface is separated from the superior surface by a sharp margin formed by a white band of fibres known as *stria habenularis*. Between the posterior end of the stria habenularis and the superior surface of the thalamus is a small triangular area known as *trigonum habenulae*. Its *lateral surface* is flat and is separated from the

lentiform nucleus by the fibres of the internal capsule. The *inferior surface* of the thalamus is directly continuous with the tegmentum of the mid-brain.

The *anterior end* of the thalamus is directed towards the median plane and forms the anterior boundary of the interventricular foramen.

The *posterior end* of the thalamus is more projecting and is known as the *pulvinar* of the thalamus. It overhangs the superior quadrigeminal body and the superior brachium. On the inferolateral aspect of the pulvinar there is a low rounded elevation known as the lateral geniculate body.

Infero-medially it is separated from a more prominent rounded body known as the medial geniculate body.

Connections of the thalamus. The three nuclei (anterior, lateral and medial), of which the thalamus is composed of, receive majority of the sensory fibres from the different parts of the body through different tracts whi h constitute its afferent connections and give rise to fresh fibres which go to the cerebral cortex, and to the caudate and the lentiform nuclei constituting its efferent connections.

Afferent tracts—

(1) Medial lemniscus (upward continuation of the column of gall and Budach) carries deep or proprioceptic and discriminative thermal and pain sensations.

(2) Spinal lemniscus (upward continuation of the spinothalamic and spinotectal tracts) carries pain, heat, cold and touch sensations.

(3) Trigeminal lemniscus carries all sorts of sensations from the trigeminal areas.

(4) Sensory visceral fibres from the hypothalamus.

(5) Mamillo-thalamic tract carrying olfactory sensations.

(6) Cerebellar efferent fibres through the superior cerebellar peduncle of the opposite side.

(7) Rubro-thalamic tract fibres of the same side.

(8) Cortico-thalamic tract fibres from the different areas of the cerebral hemispheres.

Efferent fibres of the thalamus—

(1) Thalamo-cortical fibres which are distributed to the post-central area and to other areas on the surface of the cerebral hemisphere.

(2) Efferent fibres to the caudate nucleus.

(3) Efferent fibres to the putamen of the lentiform nucleus.

Functional significance of the thalamus. From the above afferent and efferent connections it is clear that the thalamus forms the important relay station for all sorts of sensory impulses except the visual and auditory fibres and thereby establishes important correlations between different types of sensations.

Compared to the postal service the thalamus is the R. M. S. (Royal Mail Service) of sensory impulses where they are analysed, correlated with different areas and finally are despatched to their respective destinations. Some of the cruder sensory impulses are short-circuited by it and thus it acts as an important sensory reflex centre.

THE THIRD VENTRICLE OF THE BRAIN

The third ventricle of the brain is a somewhat triangular recess between the two thalami with its apex directed downwards. It has got a roof, a floor, an anterior and a posterior boundary and two lateral walls.

The **roof** is formed by a layer of ependyma which stretches between the upper edges of the lateral walls of the cavity and is continuous with the ependymal lining of the ventricle. Superiorly the roof is covered by a layer of pia mater, the tela chorioidea of the third ventricle under cover of which there lies the choroid plexus of the same.

The floor slopes downwards and forwards and is formed from before backwards by the optic chiasma, the infundibulum and tuber cinereum, corpora mamillaria, posterior perforated substance and tegmenta of the peduncles.

The **anterior wall** is formed by the lamina terminalis, anterior column of fornix and the anterior commissure. At the junction of roof with the anterior and lateral walls of the ventricle is the *interventricular foramen* through which the third and lateral ventricles communicate with each other.

The **posterior wall** is formed by the pineal body, the posterior commissure and the aqueduct of the mid-brain.

The **lateral wall** of the third ventri le consists of an upper and a lower portion. The upper portion is formed by the medial surface of the anterior two-thirds of the thalamus and the lower portion is formed by the hypothalamus. The upper and the lower portions of the lateral wall are separated from each other by the hypothalamic sulcus which curves from the interventricular foramen to the aqueduct of the mid-brain. The two lateral walls are connected to each other across the cavity of the ventricle by a band of grey matter called the *connexus interthalamicus*.

The **cavity of the third ventricle** is not self-contained within its boundary limits but it projects into blind diverticula from its walls to form small recesses. On the floor the cavity prolongs into the infundibulum forming the *infundibular recess*. On the anterior wall there are two recesses, one over the optic chiasma known as the *optic recess* and the other in between the anterior column of fornix and the anterior commissure known as vulva. On the posterior wall there lies a recess within the stalk of the pineal body known as the *pineal recess* and above that there is a second recess known as the *suprapineal recess*.

Communications—

(1) It communicates with the lateral ventricles by means of interventricular foramen.

(2) With fourth ventricle by aqueduct of the mid-brain.

The third ventricle contains the cerebro-spinal fluid which circulates into different ventricular cavities by its openings of communication.

Epithalamus. It consists of pineal body, stria habenularis and the trigonum habenulae.

Pineal body. It is a small oval body reddish-grey in colour and is situated in the depression between the two superior quadrigeminal bodies opposite the median plane. It measures about one-third inch in length and about one-sixth inch in thickness and is evaginated by a fold of pia mater. Posteriorly it forms a blunt extremity whereas anteriorly it is connected to the posterior wall of the third ventricle by a narrow stalk. The stalk consists of two laminae in between which it contains a space, the pineal recess of the third ventricle. The superior lamina of the stalk splits into two diverging processes which are continuous with the stria habenularis. Its inferior lamina curves downwards to the posterior commissure. Superiorly the pineal body is overhung by the splenium of the corpus callosum and is related to the great cerebral vein and the suprapineal recess. Inferiorly it rests on the upper depressed area of the crusiform sulcus in between the two superior quadrigeminal bodies.

Structurally it is devoid of any nervous elements and is composed of epitheloid-like cells arranged in the form of lobules.

Stria habenularis. It is a narrow band of fibres which are derived from the anterior perforated substance, olfactory tract and from the hippocampus through the fornix. It courses along the medial margin of the thalamus and reaching its posterior part it descends downwards and ends in the habenular nucleus of the same and of the opposite sides situated at the trigonum habenulae. Posteriorly some of its medial fibres are continuous with the superior lamina of the stalk of the pineal body. The

fibres which pass to the opposite side cross in the median plane with the fellow of the opposite side and form the *habenular commissure.*

Trigonum habenulae. It is a small triangular depressed area which overlies the habenular nucleus and is bounded laterally by the thalamus, medially by the posterior part of the stria habenularis and posteriorly by a groove separating it from the superior quadrigeminal body.

Matathalamus. It consists of geniculate bodies and has already been described.

Hypothalamus. It includes (1) the sub-thalamic tegmental region, (2) the structures which form the floor of the third ventricle, that is, the posterior perforated substance, the corpora mamillaria, tuber cinereum, infundibulum, hypophysis cerebri and optic chiasma, (3) the anterior part of the lateral wall of the third ventricle below and in front of the thalamus and (4) the hypo-thalamic unclei.

Hypothalamic nuclei. Hypothalamic nuclei which are situated on the lateral wall of the third ventricle below the hypothalamic sulcus are believed to be important controlling and regulating centre for the visceral activities. They consist of supra-optic nucleus, posterior hypothalamic and lateral hypothalamic nuclei.

The *supra-optic nucleus* lies close to the ventricular surface of the optic chiasma and gives out efferent fibres which pass to supply the posterior lobe of the pituitary body along the infundibulum and control the antidiuretic activities of the posterior lobe of the pituitary body. Section of these fibres destroys the antidiuretic action of the posterior lobe and causes a condition known as diabetes insipidus in which there is excessive polyuria without glycosuria.

Posterior hypothalamic nucleus lies immediately on the lateral wall of the third ventricle above the corpora mamillaria and is regarded as the higher centre for the sympathetic nervous system.

Lateral hypothalamic nucleus. It lies in front of the posterior hypothalamic nucleus on a deeper plane and is regarded as the higher centre for the para-sympathetic nervous system.

In addition to the above centres the hypothalamic region is believed to contain heat-regulating centre and the centre for sleep.

Mamillary bodies. The mamillary bodies are two in number and are placed in front of the posterior perforated substance and on either side of the median plane on the floor of the third ventricle. Each resembles a pea in appearance and consists of an outer white matter and an inner grey matter. The white matter comprises of the fibres derived from the anterior column of fornix and they partly end into the inner grey matter. The grey matter which forms its nucleus gives rise to fibres which form the mamillo-thalamic and mamillo-tegmental tracts. The former ends into the anterior nucleus of the thalamus while the latter ends in the tegmentum of the mid-brain.

Tuber cinereum. It forms a collection of grey matter and makes a low rounded elevation which is bounded in front by the optic chiasma, behind by the mamillary bodies and laterally by the anterior portion of the optic tract. From its anterior part the infundibulum of the hypophysis cerebri descends through the diaphragm sellae.

THE CEREBRAL HEMISPHERES

Each cerebral hemisphere has got three surfaces: supero-lateral, medial and inferior; four borders: supero-medial, infero-lateral, medial occipital and orbital; and two poles or ends: frontal and occipital.

The *supero-lateral surface* is convex in adaptation to the concavity of the vault of the cranium.

The *medial surface* is flat and vertical and is separated from that of the opposite side by the falx cerebri.

The *inferior surface* is of irregular form and may be divided into two parts, orbital and tentorial. The *orbital surface* is formed by the orbital surface of the frontal lobe of the brain. It is concave and rests on the roof of the orbit and nose. The *tentorial surface* is concavoconvex and is formed by the undersurface of the temporal and occipital lobes. It rests on the middle cranial fossa and the tentorium cerebelli.

The *supero-medial border* separates the supero-lateral from the medial surface. The infero-lateral border separates the supero-lateral from the inferior surface. Its anterior part separates the supero-lateral from the orbital surface and is called the superciliary border. The medial occipital border separates the medial from the tentorial surface while the medial orbital separating the medial from the orbital surface.

The anterior end of the hemisphere is known as the *frontal pole* while the posterior end as the *occipital pole*. The anterior end of the temporal lobe is known as the temporal pole.

The subdivisions of the cerebral hemisphere. Each cerebral hemisphere is subdivided into four lobes: frontal, parietal, occipital and temporal.

The *frontal lobe* constitutes the anterior part of the cerebral hemisphere and comprises of the whole of the area which lies in front of the central sulcus and above the lateral sulcus. It is limited above by the supero-medial border and below and in front by the superciliary border.

The *parietal lobe* is bounded in front by the central sulcus and behind by a line joining the pre-occipital notch, which lies on the infero-lateral border about 5 cm. in fornt of the occipital pole, to the parieto-occipital notch, which cuts the supero-medial border about 5 cm. in front of the occipital pole. Above, it is limited by the supero-medial border and below by the posterior ramus of the lateral sulcus and by a line drawn backwards to the posterior boundary from the point where the posterior ramus of the lateral sulcus turns upwards.

The *occipital lobe* comprises the portion of the brain which lies behind the line joining the parieto-occipital to the pre-occipital notcb.

The *temporal lobe* is bounded above and in front by the lateral sulcus, below by the infero-lateral border and posteriorly by the line joining the pre-occipital to the parieto-occipital notch.

THE SULCI AND GYRI ON THE SUPERO-LATERAL SURFACE

The lateral sulcus. It begins as a short stem on the inferior surface at the lateral side of the anterior perforated substance and passes forwards and laterally between the temporal pole and the orbital surface and then reaches the supero-lateral surface where it divides into three limbs or *rami*, *anterior horizontal*, *anterior ascending*, and posterior ramus. The anterior horizontal ramus runs forwards for about 2·5 cm. into the inferior frontal gyrus. The anterior ascending ramus passes upwards for about the same distance into the inferior frontal gyrus. The posterior ramus is the largest and measures about 7 cm. is length, passes upwards and backwards and ends in an upturned end which projects into the parietal lobe. The lateral sulcus contains the middle cerebral vessels and at the bottom of the sulcus there lies the insular cortex.

The central sulcus. It begins in the supero-medial margin 1·2 cm. behind the mid-point between the frontal and occipital poles and descends downwards and forwards to the upper part of the posterior ramus of the lateral sulcus from which it is separated by means of an arched gyrus. It is the admirable example of limiting sulcus and separates the pre-central area in front from the post-central area behind.

The frontal lobe. The frontal lobe of the brain consists of pre-central gyrus, lying in front of the central sulcus and behind the pre-central sulcus, and superior,

middle and inferior frontal gyri separated from one another by means of two antero-posterior sulci, superior and inferior frontal sulci.

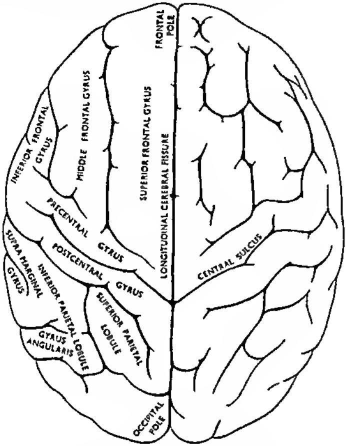


Fig 816. The cerebrum. Seen from the top.

The **parietal lobe.** It consists of post-central gyrus, and superior and inferior parietal lobules. The post-central gyrus lies behind the central sulcus and in front of the post-central sulcus which runs parallel to the central sulcus. The superior and inferior parietal lobules are separated from each other by the intra-parietal sulcus which runs backwards from the upper part of the post-central sulcus.

The **temporal lobe.** It is divided into superior, middle and inferior temporal gyri by means of superior and inferior temporal sulci.

The **occipital lobe.** The transverse occipital sulcus runs downwards from the supero-medial margin behind the parieto-occipital sulcus. It is joined in the middle by the intraparietal sulcus. The lateral occipital sulcus which runs antero-posteriorly and lies behind the transverse occipital sulcus which runs antero-posteriorly and lies behind the transverse occipital sulcus, divides the rest of the occipital lobe into superior and inferior occipital gyri. The lunate sulcus is vertically disposed opposite the occipital pole and is joined by the post-calcarine sulcus to form a "T".

THE SULCI AND GYRI ON THE MEDIAL SURFACE

The **parieto-occipital sulcus.** It lies on the posterior part of the medial surface and begins in the supero-medial margin about 5 cm. in front of the occipital pole and descends downwards and forwards to join the calcarine sulcus at an acute angle.

The **visuo-psychic area** surrounds the visuo-sensory area. Recognition and identification of objects are possible due to the presence of this area. It stores up the experiences of older objects.

Auditory area. It consists of audito-sensory and audito-psychic areas. The audito-sensory area consists of the transverse temporal gyri and a part of the superior temporal gyrus. All kinds of auditory impressions including the loudness, pitch, and quality are received in this area.

The **audito-psychic area** includes the remainder of the temporal lobe. This area maintains the function of interpretation of different auditory impressions as regards their probable source and origin by association with past experience.

Parietal area. This is included in the parietal lobe of the cerebral hemisphere and owing to its closer approximation with the different sensory areas it establishes associations with these areas so as to bring a perfection in the matter of appreciations of different sensory impulses.

Pyriform area. This area receives the olfactory neurons of the second order and gives origin to the olfactory neurons of the third order which pass into the hippocampal formation. It is concerned in the conduction of the olfactory sensation, i.e., different kinds of smell sensations.

Besides these areas there is insular area which is embedded in the insular cortex and no definite functions are known to be attributed to it up till now.

Fig. 819. The superolateral surface of the cerebrum showing the gyri and representation of the body parts in relation to the motor and sensory areas of the body. With kind permission from Callander: Surgical Anatomy W. B. Saunder's Company, Philadelphia and London.

Recent subdivisions of areas on the brain on the basis of its cytological characters. As a result of different experiments and careful consideration of the histological features of the cerebral cortex, it has been found that cytologically distinct areas on the surface of the brain have distinctive functions and accordingly it has been subdivided into the following areas which differ from one another in their cytology as well as in their functions.

Motor areas. These are the areas on the surface of the brain which on stimulation result in precise muscular movements. It has been proved by experiment that areas, 4, 6, 8, 22, 19 and 5 are the motor areas on the surface of the brain and of these the area 4 forms the primary motor area.

Area 4 This comprises of the Betz-cell area and is entirely motor in function. It occupies the anterior lip of the central sulcus (Rolandic fissure) which is formed by the posterior part of the pre-central gyrus. The cells of this area give origin to axons which form the pyramidal tract.

Area 6. This is also called the pre-motor area and occupies the greater part of the pre-central gyrus, i.e., the portion of the pre-central gyrus that lies in front of the area 4. Its cells are connected with the area 4 and they give rise to axons some of which join in the pyramidal tract, some with the extrapyramidal system and some of them are concerned with the musculature of the mouth and respiration. The lower part of area 6 (also known as areas 44 and 45), popularly known as Broca's area is concerned with speech. Autonomic motor area is stated to be embedded in this area stimulation of which causes fluctuation of systolic blood pressure and changes in the cardiac rate.

Area 8. This is also largely extrapyramidal and is concerned with eye movement. It occupies the frontal field and corresponds to posterior part of inferior and the posterior part of lower half of middle frontal gyri. Stimulation of this area causes dilatation of the pupil, opening and closure of the upper eye lid and conjugate deviation of the eyes to the opposite side.

Area 5. This area occupies the anterior part of superior parietal lobule and stimulation of this area causes the same effects as in area 22.

Area 13 or cortical respiratory centre. Recent investigation has disclosed that the area 13, situated in the posterior part of the medial orbital gyrus, controls the activities of the vagus and the respiratory movements. Stimulation of this area causes inhibition of the peristaltic movement of the gut as well as prompt arrest of respiratory movements.

Sensory areas in the cortex. The different types of afferent impulses that reach the cortex have their particular area or areas on the surface of the brain which differ in their cytology and the following different sensory areas of distinctive function have been found on the basis of experimental works done on animal and man as well.

Areas 3, 1, 2. These areas are confined to the post-central gyrus in order from before backwards and they receive most of the projections from the thalamus and are concerned in the perception of cutaneous and general kinaesthetic sensibility.

Area 5. This area occupies the anterior part of the superior parietal lobule and is partly motor and mainly sensory in function.

Area 7. This area is confined to the anterior part of the inferior parietal lobule and is also mainly sensory in function.

Areas 41 and 42 or audito-sensory area. These areas are chiefly confined to the walls of the superior temporal gyrus hidden in the floor of the lateral sulcus and also extend, to a small extent, on the superficial margin of the same gyrus. The auditory impulses from the cochlea as sensations of sounds which vary in pitch, loudness and quality reach these areas. They also receive vestibular impulses, although these impulses have more important relations to the cerebellum.

The audito-sensory area of one side represents both sides of the auditory apparatus and consequently lesion on one side of this area does not cause deafness although there is some impairment of auditory acuity. Electrical stimulation of this area causes subjective noises in both ears.

Area 22 or audito-psychic area. This area occupies the middle and the inferior temporal gyri and is concerned with the appreciation of the significance of the sounds. In a right-handed person some portion of this area on the left side is also concerned

with the understanding of spoken speech. Stimulation of this area causes auditory hallucination and movement of the head to the opposite side.

Area 17 or striate area or visual centre. This area is situated on the walls of the calcarine fissure and on section this area presents a conspicuous striations known as line of Gennari and can be easily seen in unaided eyes. Due to the presence of their striations this area also called the *striate area.* It receives all kinds of visual impressions.

Areas 18 *and* 19. The area 18 lies in the upper part of the occipital pole while the area 19 is situated in the posterior part of the inferior parietal lobule and in the adjoining parts of the temporal gyri. These areas are concerned with the association of visual and other impulses and it is here that the visual, tactile, and to a lesser extent, auditory impressions are co-related and are synthesised to form proper visual perception and appreciation. Injury to these areas results in loss of visual appreciations in which written or printed matters are not understood.

Smell and taste centre. It is confined to the lower part of the post-central gyrus. Formerly it was believed that they are in the uncus and the anterior part of the hippocampal gyrus.

The commissural fibres. The commissural fibres are those which connect the corresponding areas in the two cerebral hemispheres to each other. The corpus callosum is the largest of the commissural fibres and connects one cerebral hemisphere with the other. *Anterior commissure* connects olfactory bulb, olfactory pyramid, and pyriform area of one side with that of the other. *Hippocampal commissure* connects the two hippocampal formations to each other.

Corpus callosum. It is the largest band of commissural fibres and forms a transverse arch which curves from before backwards in the middle line, between the cerebral hemispheres. It is about 4 inches long and its central portion is about one inch in breadth. It forms the floor of the longitudinal cerebral fissure and forms the roof, part of the floor and anterior wall of the lateral ventricle. It is thicker at the ends than in the middle of its extent. In front it turns downwards and backwards upon itself, making a knee-shaped bend, the *genu.* Diminishing much in thickness and curving backwards on the upper surface of the lamina terminalis is the *rostrum.* The *trunk* of the corpus callosum arches backwards from the genu with an upward convexity and ends posteriorly into a thickened extremity called the *splenium.*

The upper surface of the trunk and splenium and the anterior aspects of the genu are covered with a thin layer of grey matter known as *indusium griseum,* and in it are embedded two fine longitudinal bundles of fibres on each side which are termed the *medial* and *lateral longitudinal striae.* The splenium of the corpus callosum overhangs the pineal body, corpora quadrigemina and the pulvinar of the thalami. On each side of the median plane, the upper surface of the corpus callosum is overlapped by the gyrus cinguli. Inferiorly the trunk, posteriorly the genu and superiorly the rostrum, in the median plane, give attachment to theseptum lucidum and form on each side of the median plane, the roof, anterior wall and floor of the lateral ventricle respectively.

The fibres of the rostrum connect the orbital surfaces of the two frontal lobes. The fibres of the genu curve forwards and connect the lateral and medial surfaces of the two frontal lobes, constituting the *forceps minor.* The fibres of the trunk connect the wide cortical areas of one hemisphere with that of the other. Those fibres of the trunk and splenium which form the roof and the lateral wall of the posterior horn and the lateral wall of the inferior horn of the lateral ventricle, constitute the *tapetum.* The remaining fibres of the splenium curve backwards and connect the two occipital lobes and form the *forceps major.*

The association fibres. The association fibres are those which connect cortical areas of the same hemisphere to one another. They are of two kinds

(*a*) short association fibres connecting adjacent gyri to one another, (*b*) long association fibres connecting more widely separated gyri to one another.

(*a*) *Short association fibres* connect the adjacent gyri to one another and lie within or just beneath the cortex.

(*b*) *Long association fibres* are grouped into bundles and are of considerable length and they are usually situated on a deeper plane. The following fasciculi may be distinguished.

(1) The *uncinate fasciculus.* It connects the gyri on the orbital surface of the frontal lobe with the anterior part of the temporal lobe.
(2) The *cingulum.* These are long curved bundles and lie within the gyrus cinguli and so follow the curve of the gyrus.
(3) *Superior longitudinal fasciculus.* This is the largest of all association bundles. It begins in the anterior part of the frontal region, arches backwards and upwards and connects the frontal lobe with the occipital and temporal lobes.
(4) *Fronto-occipital fasciculus.* This fasciculus begins in the frontal lobe and connects it with the occipital and temporal lobes.

The itinerant fibres. The itinerant fibres are those nerve fibres which connect the cerebral cortex with the lower part of the brain and the spinal cord and include both corticofugal and corticopetal fibres. The fibres of the internal capsule are the best example of them.

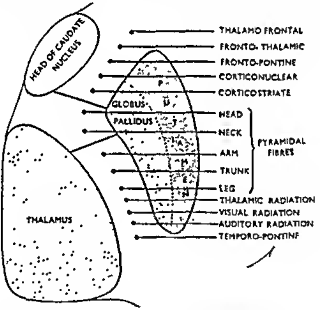


Fig. 820. The internal capsule with the arrangements of the fibres.

The internal capsule. It is a relatively thick lamina of white substances by means of which associations are established between the cortex of the hemisphere, its basal nuclei, the lower part of the brain and the medulla spinalis. It is bent on itself with an outward concavity and lies between the caudate nucleus and the thalamus on the medial side and the lentiform nucleus on the lateral side, but it extends both anterior and posterior to lentiform nucleus. It is continuous below with the cerebral peduncle (basis pedunculi) and above with corona radiata.

It is divided into four parts: an anterior limb (frontal part), genu, a posterior limb (occipital part) and a retro-lentiform part.

The *anterior limb*. It is interposed between the lentiform nucleus on the lateral side and the head of the caudate nucleus on the medial side. It contains the thalamo-frontal, fronto-thalamic and fronto-pontine fibres which arise in the cortex of the frontal area and are relayed in the nuclei pontis; the other fibres are cortico-nuclear and corticostriate.

Genu. It consists of fibres which convey motor impulses from the motor area of the cortex of the hemisphere to the nuclei of the nerves which supply the muscles of the eyes, head, mouth, tongue and larynx of the opposite side in order.

Posterior limb. It is divided into anterior 2/3 and posterior 1/3. The anterior 2/3 carries the motor fibres to the nuclei of the nerves which supply the muscles of the neck, upper limb, trunk and lower limb of the opposite side in order from before backwards. The posterior 1/3 of the posterior limb carries majority of the sensory fibres conveying ordinary sensory impulses to the sensory areas on the cortex of the hemisphere and some of the motor fibres (temporo-pontine fibres) which arise in the cortex of the temporal lobe and are relayed in the nuclei pontis and then carried to the opposite cerebellum, and cortico-thalamic fibres, which arise chiefly in the temporal and occipital areas and pass to the lateral nucleus of the thalamus.

Retro-lenticular part. The fibres of the optic radiation occupy the anterior part and the auditory radiation fibres occupy the posterior part of the retro-lenticular part of the internal capsule.

The fornix. The fornix is the efferent pathways from the cells of the hippocampal formation. The fibres of the cells of the hippocampus pass to its ventricular surface where they form a layer of white fibres, termed the alveus. The fibres of the alveus converge on the medial margin of the hippocampus to form the fimbria from which the fornix commences as two riband-like bands. At first the two bands, one on each side, wind round the posterior end of the thalamus and then converge together to meet in the middle line to form a triangular shaped mass of white matter, the body of the fornix. From the anterior end of the body, the two bands diverge from each other to end into the corresponding mamillary body. Thus we see that in the central part of their course in the median plane the bands unite to form the body of the fornix but remain separate both in front and behind as four columns, two anterior and two posterior.

The *two posterior columns* of the fornix are closely applied to the undersurface of the corpus callosum and are connected to each other by transverse fibres which connect the two hippocampal formations to each other and constitute the hippocampal commissure.

The *body of the fornix* lies over the tela chorioidea and ependymal roof of the third ventricle. Above and posteriorly it is attached to the undersurface of the corpus callosum and above and anteriorly to the lower border of the septum lucidum. Below and laterally it rests on the thalamus.

The *anterior column of fornix* during its course to the corpus mamillare passes in front of the interventricular foramen and behind the anterior commissure.

The pyramidal tract. These fibres take origin from Betz's cells in the upper three-fourths of the pre-central convolution and from the adjacent para-central lobule. At their commencement they form a fan-shaped group of fibres which traverse the corona radiata and descending through the genu and the anterior two-thirds of the posterior limb of the internal capsule, they enter the central division of the basis pedunculi of the cerebral peduncles through which they pass to the basilar part of the pons and then to the pyramid of the medulla. At the lower limit of the medulla, the motor strand splits up into three groups of fibres; the chief group decussates at the bottom of the anterior median fissure with those of the opposite side and then descends as the *lateral cerebro-spinal tract*, in the opposite lateral white column, ending around cells in the base of the posterior grey column. Fresh fibres carry the impulses to the multipolar nerve cells of the anterior grey column. Another group of fibres passes from the medulla to the anterior white column of the same

side forming the *anterior cerebro-spinal tract.* They cross over individually at a lower level through the anterior commissure to the grey matter of the opposite side of the spinal cord. The third group forms the smallest one; it consists of fibres which blend with pyramidal fibres that have already crossed from opposite side.

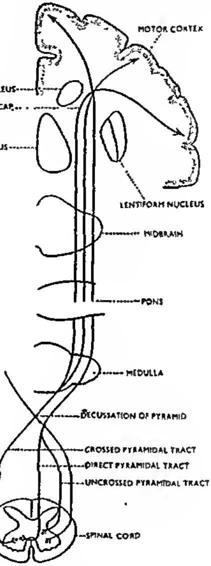


Fig. 821. The pyramidal tract.

In the internal capsule the head fibres descend in the genu while those of the arm, trunk and leg pass through the posterior limb, arranged in that order from before backwards. During their course through the basis pedunculi the order is head, arm, trunk and leg from within outwards.

The lentiform nucleus. The lentiform nucleus is burried within the substance of the cerebral hemisphere and constitutes the extra ventricular part of the corpus striatum. It is placed lateral to both caudate nucleus and thalamus, being separated from them by a strand of nerve fibres called the internal capsule. In a horizontal section it appears as a longitudinal grey mass, shaped like a double convex lens. In a coronal section it is triangular in shape with its base laterally. Intersected by

two white laminae it is divided into three parallel strands, medial, intermediate, and lateral. The medial and intermediate portions, have a paler colour, hence the name *globus pallidus* is applied to them. The lateral segment is darker and is called *putamen*. In front and below at the base of the cerebrum, the caudate and lentiform nuclei *are continuous with each other and with the grey matter at the anterior*

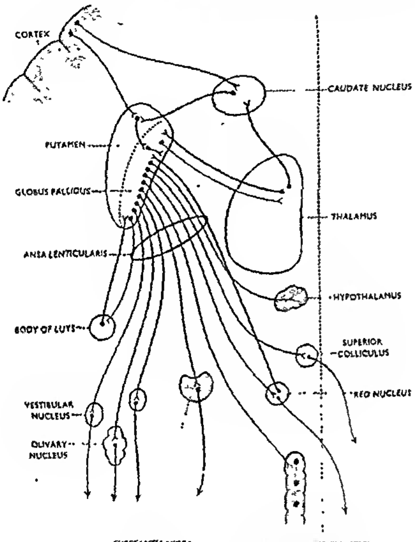


Fig. 822. The connections of the corpus striatum.

perforated substance. Laterally the lentiform nucleus is covered by a thick layer of white substance, the *external capsule*, which separates it from the *claustrum*, a thick layer of grey substance on the outer side of the external capsule. Medially it is separated from the caudate nucleus in front, and thalamus behind, by the internal capsule. Round the anterior, superior and posterior margins the nucleus is related to the fibres of the corona radiata. Inferiorly it is grooved by the fibres of the anterior commissure and the *lateral striate artery at first lies inferiorly and then on its lateral aspects before it pierces the substance of the nucleus.*

The caudate nucleus. The caudate nucleus is buried in the substance of the cerebral hemisphere and constitutes the intra-ventricular portion of the corpus striatum. It helps in the formation of the floor of the anterior horn and the floor of the body of the lateral ventricle and also the roof of the inferior horn of the same.

Each caudate nucleus forms an arched mass of grey matter and presents anteriorly a massive rounded projection known as the head of the caudate nucleus. From the head the nucleus gradually diminishes in size and constitutes its body and tail respectively.

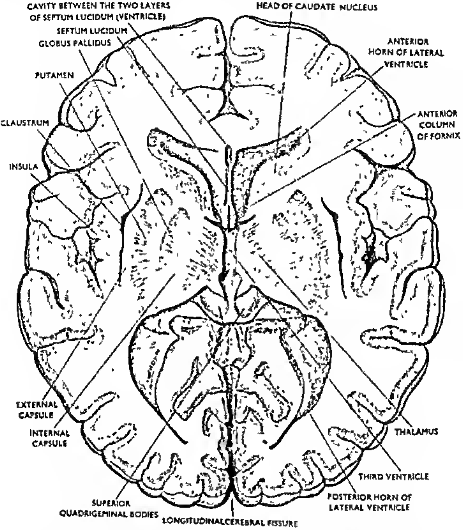


Fig 823. A horizontal section of the brain showing the corpus striatum.

The *head* of the caudate nucleus forms the greater part of the floor of the anterior horn of the lateral ventricle and this surface is covered by the ventricular ependyma. It is related above to the corpus callosum. Laterally it is separated from the lentiform nucleus by the anterior limb of the internal capsule. Superiorly the margin of the head is related to the fronto-occipital fasciculus. Posteriorly it is continuous with the body.

Body. The body of the caudate nucleus forms the floor of the body of the lateral ventricle. Its ventricular surface is covered by ventricular ependyma and this surface is related to the thalamostriate vein, stria semicircularis and the thalamus. Laterally it is related to the fronto-occipital fasciculus and the corona radiata. Posteriorly it is continuous with the tail.

Tail. The tail of the caudate nucleus runs forwards in the roof of the inferior horn of the lateral ventricle with the stria semicircularis on its medial side. As the

body curves downwards and forwards into the tail, it passes below the fibres of the corona radiata, putamen of the lentiform nucleus and the ansa lenticularis. Anteriorly the tail is continuous with the amygdaloid nucleus.

The lateral ventricles. The lateral ventricles are two irregular cavities, right and left, hollowed out in the substance of the cerebral hemispheres. They are placed side by side but are separated in the middle line by a thin, vertical partition, the *septum lucidum*.

Each ventricle consists of a central part or body and three prolongations or recesses called the anterior, posterior and inferior cornua.

The *body* of the lateral ventricle extends from the inter-ventricular foramen to the splenium of the corpus callosum. It is deeper in front than behind and deeper near the middle line than at the sides, where the roof and the sloping floor meet and blend with the substance of the hemisphere. The body of the lateral ventricle is triangular in shape and has got a roof, a floor and a medial wall. The roof is formed by corpus callosum. The floor slopes from above downwards and medially and is formed from lateral to medial side by the caudate nucleus, stria semicircularis, thalamostriate vein, upper surface of the thalamus, choroid plexus and the fornix. Its medial wall is formed by the septum lucidum.

The *anterior cornu* passes forwards, laterally and slightly downwards into the frontal lobe. Its roof is formed by the corpus callosum and floor by the head of the caudate nucleus and for a small portion by the upper surface of the rostrum of the corpus callosum.

The *posterior cornu* passes backwards and medially into the occipital lobe. Its roof and lateral wall are formed by the fibres of the tapetum of the corpus callosum. The fibres of the splenium of the corpus callosum pass medial to the posterior cornu and form an evagination there, the *bulb* of the posterior cornu. Below the bulb there is a second elevation, the *calcar avis* caused by the calcarine sulcus. Posteriorly the lateral and medial walls meet together.

The *inferior cornu*, the largest of the three, traverses the temporal lobe and courses round the posterior end of the thalamus. It passes at first backwards, laterally and downwards and then curves forwards to within 2·5 cm. of the apex of the temporal lobe. Its roof is formed by the fibres of the tapetum of the corpus callosum, tail of the caudate nucleus, stria semicircularis, and more anteriorly, by the amygdaloid nucleus. Its floor is formed by the choroid plexus, the fimbria hippocampi, the hippocampus, and the collateral eminence.

Communications:

(1) With the third ventricle through the interventricular foramen.
(2) With each other through the third ventricle. It contains carebrospinal fluid in abundance.

The choroid plexus. The choroid plexus is a highly vascular fringe of pia mater which secretes cerebrospinal fluid into the different ventricular cavities but that in the lateral ventricle is very prominent and the bulk of the cerebrospinal fluid is secreted by it. The choroid plexus of the lateral ventricle is a highly vascular fringe of pia mater which projects into the ventricular cavity invaginating the ependymal medial wall of the ventricle and receiving from it a complete investment. It extends as far forwards as the interventricular foramen where it is continuous with the corresponding plexus of the opposite side. It consists of minute and highly vascular villous processes each possessing an afferent and efferent blood vessels. The arteries of the plexus are the anterior choroid artery, a branch of the internal carotid artery, which enters the plexus at the anterior end of the inferior horn of the lateral ventricle, and one or two posterior choroid arteries, branches of the posterior cerebral artery which enter into the plexus through the upper part of the choroidal fissure. The veins of the plexus unite to form a single tortuous vein (the choroid vein) which begins in the inferior horn of the ventricle and courses in the plexus to

the interventricular foramen where they join with the corresponding thalamostriate vein to form the corresponding internal cerebral vein. The two internal cerebral veins run backwards close to the median plane between the two layers of the tela chorioidea of the third ventricle and reaching below the splenium of the corpus callosum, where the two layers of the tela chorioidea separate from each other, they unite to form the great cerebral vein which curves backwards and upwards behind the splenium to join the straight sinus.

The tela chorioidea. The tela chorioidea is a fold of pia mater which enters the brain through the transverse fissure of the cerebrum, a gap below the splenium of the corpus callosum. It appears in both the lateral and the third ventricles though separated from their cavities by the epithelium of the ependyma. It is triangular in shape, with its apex forwards and base backwards. It has the same extent as the body of the fornix, so that it reaches from the inerventricular foramen in front to the back part of the splenium behind, beneath which, after investing the pineal body, it becomes continuous with the remainder of the pia mater covering the cerebrum and cerebellum. The tela sweeps round the posterior parts of the thalami to pass into the inferior cornua of the lateral ventricles through the choroidal fissure. Anteriorly it protrudes beneath the choroidal fissure opposite the two thalami and thus roofing in the third ventricle and forming the tela chorioidea of the third ventricle. The pia mater covering of the roof of the fourth ventricle constitutes the tela chorioidea of the fourth ventricle and contains the choroid plexus for the same.

The interpeduncular fossa. It is a lozenge-shaped fossa at the base of the brain and is bounded in front by the optic chiasma, behind by the upper surface of the pons, antero-laterally by the converging optic tracts and postero-laterally by the diverging cerebral peduncles. On the floor of the fossa there are structures which form the hypothalamus and they, from before backwards, are the following: tuber cinereum, infundibulum, hypophysis cerebri, corpora mamillaria, and posterior perforated substance. It contains the circulus arteriosus and the roots of the oculomotor nerve.

THE CRANIAL NERVES

Numerical value of the cranial nerves:

1. First cranial nerve .. Olfactory.
2. Second cranial nerve .. Optic.
3. Third cranial nerve .. Oculomotor.
4. Fourth cranial nerve .. Trochlear.
5. Fifth cranial nerve .. Trigeminal.
6. Sixth cranial nerve .. Abducent.
7. Seventh cranial nerve .. Facial.
8. Eighth cranial nerve .. Stato-acoustic (Auditory).
9. Ninth cranial nerve .. Glossopharyngeal.
10. Tenth cranial nerve .. Vagus.
11. Eleventh cranial nerve .. Accessory.
12. Twelfth cranial nerve .. Hypoglossal.

The point of exit or entrance of the respective cranial nerves from or to the cranial cavity:

1. *Olfactory*. It enters the cranium through the openings in the cribriform plate of the ethmoid bone.

2. *Optic*. It enters the cranium through the optic foramen in the sphenoid bone.

3. *Oculomotor nerve*. It emerges from the cranium into the orbit through the superior orbital fissure.

4. *Trochlear nerve*. It emerges from the cranium into the orbit through the superior orbital fissure.

5. *Trigeminal nerve.* It divides into three branches namely, ophthalmic, maxillary and mandibular. The ophthalmic branch comes through the superior orbital fissure; the maxillary division emerges through the foramen rotundum of the sphenoid; and the mandibular nerve passes through the foramen ovale of the sphenoid bone.

6. *Abducent nerve.* It emerges through the superior orbital fissure.

7. *Facial nerve.* From the cranial cavity it enters the internal auditory meatus and then after a short course through the petrous part of the temporal bone it comes out from the cranium through the stylomastoid foramen.

8. *Stato-acoustic (Auditory).* It enters the cranium through the internal auditory meatus of the temporal bone.

9. *Glossopharyngeal nerve.* It emerges from the intermediate compartment of the jugular foramen.

10. *Vagus nerve.* It comes out through the intermediate compartment of the jugular foramen.

11. *Accessory.* It comes out through the intermediate compartment of the jugular foramen.

12. *Hypoglossal nerve.* It emerges from the cranium through the hypoglossal (anterior condylar) canal of the occipital bone.

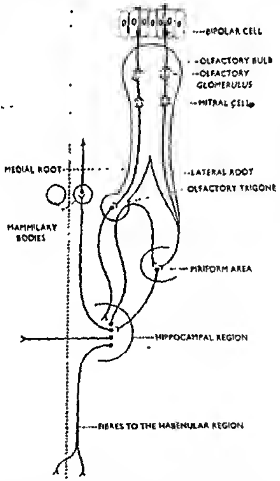


Fig. 824. The olfactory nerve and its subsequent pathways.

THE OLFACTORY NERVE AND THE PATH OF OLFACTORY OR SMELL SENSATIONS

The olfactory nerve is the first cranial nerve which is entirely sensory in function and

carries smell sensations from the olfactory area of the nasal cavities to the gyrus cinguli.

The olfactory nerve begins as central processes from the olfactory cells situated in the olfactory area of the nasal cavity. The olfactory area corresponds to the region of the superior nasal concha and the adjoining portions of the nasal septum.

From their origin the olfactory nerve fibres, which are about twenty in number, pierce the cribriform plate of the ethmoid bone and at once end in the olfactory bulb (*first olfactory neuron*).

Relay fibres from the olfactory bulb form the *olfactory tract fibres* which constitute the *second olfactory neuron* and end in the olfactory pyramid, anterior perforated substance and in the piriform area. *Third olfactory neurons* from these areas pass directly to the hippocampal and the dentate gyri (hippocampal formation). *Fourth olfactory* neurons begin as efferent fibres from the hippocampal formation and form the alveus and the fornix (posterior column of fornix, body of the fornix, anterior column of fornix). The fornix ends in the corpora mamillaria from where relay fibres form the mamillo-thalamic tract which ends in the anterior nucleus of the thalamus. Finally relay fibres from the thalamus pass to the gyrus cinguli of the cerebral cortex.

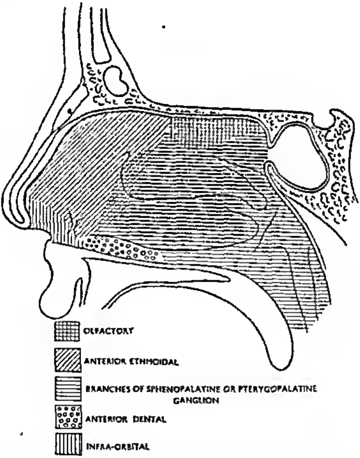


Fig. 825. The general distribution of nerves to the lateral nasal wall. With kind permission from Prof. Hollinshed, Ph.D., Anatomy for the Surgeons, Vol. I, Paul B. Hoeber INC.

N.B. Meningeal coverings of the brain are prolonged on to the olfactory nerve as it passes through the cribriform plate of the ethmoid and consequently the sub-arachnoid space is carried down into the nasal cavity along with the olfactory nerve. Thus spread of infection to the cerebral meninges may take place in case of nasal suppuration through the meningeal coverings of the olfactory nerve.

THE OPTIC NERVE

It is the second cranial nerve, entirely sensory in function and carries visual sensations from the retina to the cuneus of the occipital lobe of the brain. It is divisible into three constitutent parts, namely optic nerve, optic chiasma and the optic tract. The optic nerve extends from the retina to the anterior end of the optic chiasma; the optic chiasma is the decussating point of the optic nerve where its nasal fibres cross each other to gain the opposite side; the optic tract begins from the posterior end of the optic chiasma and having a cell station in the lateral geniculate body ends in the cuneus of the occipital lobe of the brain.

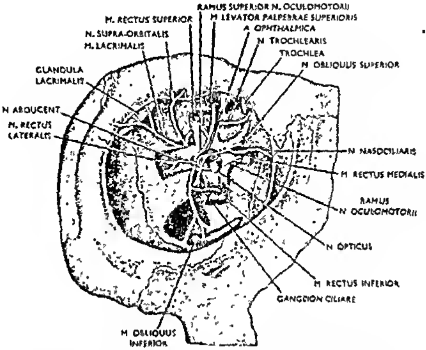


Fig. 826. The optic nerve in the anulus tendineus communis as seen from the front after removal of the eye-ball. With kind permission from Callander: Surgical Anatomy, W B. *Saunders's Company, Philadelphia and London.*

The optic nerve begins as numerous nerve filaments in the gnaglionic layer of the retina (innermost layer) and after piercing the outer layers of the retina, choroid and the lamina cribrosa of the sclera unite together to form a nerve bundle the optic nerve; it emerges from the eye-ball about 1/6 inch to the nasal side of its centre and then passing through the orbital cavity it enters the cranial cavity through the optic foramen and after a short course there it ends in the optic chiasma. It is about one and a half inches in length of which orbital part is one inch and the cranial part is half an inch.

In the orbit, the optic nerve is crossed superficially by the superior ophthalmic vein, ophthalmic artery and the nasociliary nerve from lateral to the medial side. Close to the optic foramen it is closely surrounded by the muscles of the eye-ball but in the orbit it is separated from them by a considerable distance. Between it and the rectus lateralis there lies the ciliary ganglion which gives out the short ciliary nerves which closely follow the optic nerve. The nasociliary nerve as it crosses the optic nerve gives out 2 or 3 long ciliary nerves which accompany the short ciliary nerves. The branch from the oculomotor which supplies the medial rectus passes below it in its course.

In the optic foramen the ophthalmic artery lies infero-lateral to it and in the cranial cavity the internal carotid artery bears an immediate lateral relation to it. The central artery and vein of the retina pierce the inferomedial aspect of the optic nerve at a distance of about 12 mm. (about 1/2 an inch) from the eye-ball.

Optic chiasma. The optic chiasma or the decussating optic nerves forms a quadrilateral flattened nerve bundle situated at the base of the brain opposite the junction of the floor and the anterior wall of the third ventricle and forms the anterior boundary of the interpeduncular fossa. Its anterolateral angle is continuous with the optic nerve and its posterolateral angle with the optic tract.

Superiorly it gives attachment to the lamina terminalis. Antero-inferiorly it rests upon the diaphragm sellae which separates it from the pituitary body or the hypophysis cerebri. Postero-inferiorly it gives attachment to the infundibulum or the stalk of the hypophysis cerebri.

N.B. Peculiarities of the optic nerve: (1) It is not a true nerve but a prolongation of the brain (2) It has no neurilemma sheath. (3) It is partly myelinated (the intra-ocular part within the eye-ball has no myelin sheath while the intracranial part has myelin sheath). (4) It beings as a connector neuron but not as a receptor neuron and thus it differs from other nerves

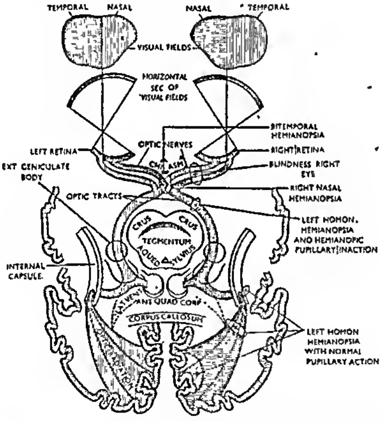


Fig. 827. The path of vision. With kind permission from Callander: Surgical Anatomy, W. B. Saunder's Company, Philadelphia and London.

Vascular relation. It is surrounded by the circulus arteriosus and is related laterally with the internal carotid artery, anteriorly with the anterior cerebral and the anterior communicating arteries and posteriorly with the posterior communicating artery.

N.B. The anterior cerebral artery crosses the optic nerve just before it joins in the chiasma while the posterior communicating artery crosses the optic tract to gain the postero-lateral part of the chiasma in its course to join the posterior cereberal artery.

Constituent fibres. The nasal fibres including the nasal half of the macular fibres of each optic nerve decussate with each other at the chiasma and pass to the opposite optic tract and occupy the central part of the chiasma. The temporal fibres of the optic nerve do not decussate but they pass to the optic tract of the same side and occupy the lateral portions of the optic chiasma.

The ventral and dorsal supra optic decussation fibres which do not form any part of the optic nerve fibres lie along the dorsal border of the chiasma and they arise from the brain stem of one side, decussate with the fibres from the opposite side and connect the brain stem with the mid-brain and fore-brain of the opposite side.

Optic tract. The optic tract begins at the posterolateral angle of the optic chiasma and contains fibres from the temporal half of the same retina and nasal half of the opposite retina.

The optic tract fibres wind round the upper part of the cerebral peduncles and end into the lateral geniculate body, superior quadrigeminal body and into the pretectal region. Fresh relay fibres from the lateral geniculate body form the geniculo-calcarine tract and then pass at first forwards and laterally along the inferior horn of the lateral ventricle and then curves lateralwards to pass through the sublenticular part of the internal capsule and finally they turn backwards through the internal sagittal stratum of the temporal and occipital lobes to end into the striate area of the occipital lobe of the brain.

The fibres that end in the pretectal region are all concerned with the pupillary light reflex while the fibres ending in the superior quadrigeminal body are concerned with somatic optic reflexes such as movement of the head and eyes in response to exteroceptive stimuli.

Effects of injury to the visual pathway:

(*a*) *Lesion in the optic chiasma* (central part). It causes bitemporal hemianopia; lesion in the peripheral part causes binasal hemianopia; in both the cases light reflex is abolished.

(*b*) *Lesion in the optic nerve.* It causes abolition of the light reflexes from the blind side of the retina.

(*c*) *Lesion in the optic tract.* Lesion beyond the lateral geniculate body causes loss of vision of the nasal part of the same side and temporal part of the opposite side of the field of vision.

THE OCULOMOTOR NERVE

It is a true motor nerve supplying almost all the ocular muscles except the rectus lateralis and obliquus superior. It also supplies motor filaments to the sphincter pupillae and the ciliaris muscles.

Deep origin. It arises from the motor nucleus of the nerve situated in the grey matter at the upper part of the floor of the aqueduct of the mid-brain and also extending into the third ventricle.

Morphologically it contains both somatic and visceral motor fibres. Its somatic fibres have their cells of origin from the *dorsilateral*, *ventrimedial*, *central* and *caudal central nuclei* of the composite oculomotor nerve nucleus and supply all the muscles of the eye-ball except the lateral rectus and the superior oblique muscles of the eye-ball. The visceral motor fibres have their cells of origin from the *Edinger-Westphal nucleus*, a member of the composite oculomotor nucleus and they supply the sphincter pupillae and the ciliaris muscle.

Superficial origin. The roots of the nerve emerge from the groove on the medial aspect of the cerebral peduncle and proceed forwards in the interpeduncular cistern.

Course and relation. After its exit from the brain it lies in between the posterior cerebral and superior cerebellar arteries in the interpeduncular fossa. It then

pierces the arachnoid mater and lies in the triangular interval between the free and the attached borders of the tentorium cerebelli and then perforates the meningeal layer of the dura mater at the lateral side of the posterior clinoid process of the sphenoid and enters into the cavernous sinus. In the cavernous sinus it lies on its lateral wall being placed above the trochlear nerve. It then passes forwards within the sinus and reaches the superior orbital fissure where it is crossed superficially by the trochlear nerve and divides into superior and inferior branches which enter the orbit through the common tendineus ring and being separated from each other by the intervening nasociliary nerve.

Distribution. The superior branch ascends on the lateral side of the optic nerve and supplies the rectus superior and levator palpebrae superioris. The inferior branch divides into three branches, one supplies the rectus medialis, the second supplies the rectus inferior and the third supplies the obliquus inferior. From the nerve to the obliquus inferior one branch passes to join the ciliary ganglion through which it supplies the sphincter pupillae and the ciliaris muscles. This short branch to the ciliary ganglion constitutes its para-sympathetic root.

Connections. (1) It is connected with the pyramidal fibres of the opposite side; (2) with the fourth, sixth and eighth cranial nerves by the medial longitudinal bundle, (3) with the visual cortex by tectobulbar tract.

Communications. In the cavernous sinus it communicates with the carotid plexus of sympathetic and the ophthalmic division of the trigeminal nerve; in the orbit it communicates with the ciliary ganglion.

Paralysis of the oculomotor nerve:

Effects. (1) Drooping of the upper eye lids (ptosis) due to paralysis of the levator palpebrae superioris.

(2) The eye is motionless and there is divergent squint in which the eye-ball is rotated lateralwards due to unopposed action of the rectus lateralis which is supplied by the sixth nerve.

(3) There is dilatation of the pupil due to unopposed action of the dilator pupilae which is supplied by the sympathetic and there is associated diplopia (double vision).

THE TROCHLEAR NERVE

The trochlear nerve is entirely motor in function and supplies the superior oblique muscle of the eye-ball.

Deep origin. It arises from its nucleus situated at the floor of the aqueduct of the mid-brain opposite the upper part of the inferior quadrigeminal body.

Morphologically the trochlear nerve contains only the somatic motor fibres.

Superficial origin. It emerges from the brain below the inferior quadrigeminal body on the side of the frenulum veli.

Course and relation. After its exit from the side of the frenulum veli it winds round the cerebral peduncle and passes forwards between the posterior cerebral and the superior cerebellar arteries. It then pierces the inner layer of the dura mater at the free border of the tentorium cerebelli a little behind the posterior clinoid process of the sphenoid and enters the cavernous sinus where it lies at its lateral wall being placed below the oculomotor nerve and above the ophthalmic nerve. Maintaining this relation it passes to the superior orbital fissure where it crosses superficial to the oculomotor nerve and then enters the orbit superficial to the common tendineus ring and the ocular muscles. In its course through the orbit it passes over the origin of the levator palpebrae superioris and lies on the medial side of the frontal nerve. It finally enters the medial surface of the superior oblique muscle and supplies it.

Peculiarities. It is the slendermost cranial nerve and is the only one which is emerging from the dorsal region of the brain stem. The fibres in their course through the mid-brain decussate with one another.

Connections. (1) It is connected with the pyramidal fibres of the opposite side; (2) with the third, sixth and eighth cranial nerves by the medial longitudinal bundle; (3) with the visual cortex by the tectobulbar tract.

Communications. In the cavernous sinus it communicates with the ophthalmic nerve and the carotid plexus of sympathetic, in the superior orbital fissure it sometimes communicates with the lacrimal nerve.

Paralysis of the trochlear nerve:

Effects. Obvious defects are not noticeable but a phenomenon known as Erb's syndrome is noticed in which there is deviation of the eye-ball upwards and inwards on lowering the object in front of the eye and the eye-ball simply moves upwards when it is turned towards the healthy side and there is also associated diplopia.

THE TRIGEMINAL NERVE

It is a mixed nerve and consists of both motor and sensory roots. The two roots of the nerve are attached to the brain stem on the upper part of the ventral aspect of the pons (superficial origin) and the small motor root usually lies in front of the sensory root.

(*a*) The *motor root* arises from the motor nucleus of the nerve situated within the dorsal or tegmental part of the pons.

(*b*) The *sensory root* forms the central processes of the cells of the semilunar ganglion of the trigeminal nerve situated in a depression on the anterior surface of the petrous part of the temporal bone immediately behind its apex. The sensory root fibres enter the substance of the pons at the superficial origin of the nerve and then divides into ascending and descending branches.

The ascending branches end in the superior sensory nucleus situated within the dorsal part of the pons ventrilateral to the motor nucleus. These fibres carry tactile, pressure and proprioceptive sensations from the trigeminal area.

The descending branches form the spinal tract of the trigeminal nerve which ends in the nucleus of the same situated within the medulla and extending downwards into the medulla spinalis for a considerable distance (upto fifth cervical segment).

This *spinal tract of the trigeminal nerve* carries painful and thermal stimuli from the trigeminal area and lies superficial to its nucleus close to the surface of the medulla and the medulla spinalis. In trigeminal neuralgia operative division of this tract ensures relief of pain.

Morphologically the trigeminal nerve contains somatic sensory fibres from the trigeminal area (head region) and branchial motor fibres for the muscles of mastication.

The *mesencephalic root of the trigeminal nerve* arises from the mesencephalic nucleus situated within the mid-brain on the lateral side of the central grey matter and its fibres join the main trunk and pass through the semilunar ganglion uninterrupted. They are concerned with proprioceptive sensations from the muscles of mastication and the muscles of the orbit.

Branches of the trigeminal nerve. The branches of the trigeminal nerve are the ophthalmic or V'I, maxillary or V'II and the mandibular or V'III.

Ophthalmic nerve. The ophthalmic nerve is the first branch of the fifth nerve (v'I) and arises from the anteromedial part of the trigeminal ganglion. It is entirely sensory in function and supplies the eye-ball, the lacrimal gland, part of the conjunctiva, part of the mucous membrane of the nose, the skin of the eyelid and the forehead and the scalp.

It measures about one inch in length and is the smallest branch of the trigeminal nerve. It passes through the lateral wall of the cavernous sinus being placed below the oculomotor and the trochlear nerves and reaching the superior orbital fissure it ends by dividing into lacrimal, frontal and nasociliary nerves.

Branches of the ophthalmic nerve. The opthalmic nerve divides into three branches, lacrimal, frontal and nasociliary and gives off communicating branches to the oculomotor, trochlear and abducent nerves and a recurrent branch which ascends upwards along the trochlear nerve and supplies the tentorium cerebelli.

Lacrimal nerve. It enters the orbit through the lateral part of the superior orbital fissure and accompanying the lacrimal artery runs along the upper border of the rectus lateralis muscle to the lacrimal gland. After supplying a few branches to the lacrimal gland it pierces the orbital septum and ends in the skin of the upper eyelid and joins with the branches from the facial nerve. In the orbit it is joined by a filament from the zygomatic branch of the maxillary nerve.

Supratrochlear nerve. The supratrochlear nerve communicates with the infratrochlear nerve and accompanying the supratrochlear artery it ascends upwards over the supratrochlear notch and then passes upwards under cover of the corrugator supercilli and frontal belly of the occipito-frontalis and by piercing these muscles it supplies the skin of the lower part of the forehead as far as the median plane. It also supplies the skin and the conjunctiva of the upper eyelid.

Supraorbital nerve. The supraorbital nerve passes between the roof of the orbit and the levator palpebrae superioris and ascends upwards through the supraorbital notch or foramen and enters into the frontal region. Then it divides into a lateral and a medial branch. Each passes upwards under cover of the frontal belly of the occipito-frontalis and finally pierces the epicranial aponeurosis and supplies the skin as far as the lambdoid suture. In its course it is accompanied by the supraorbital artery. In its course through the orbit it supplies the skin and the conjunctiva of the upper eyelid.

Nasociliary nerve. After its origin from the ophthalmic nerve it passes forwards and enters the orbit through the common tendineus ring where it lies in between the two rami of the oculomotor nerve. It then crosses the optic nerve with the ophthalmic artery and passes below the rectus superior and the obliquus superior muscle and finally reaches the medial wall of the orbit. Here it enters the anterior ethmoidal canal as the anterior ethmoidal nerve and passes into the cranial cavity. Then it passes forwards through the groove on the upper and lateral part of the cribriform plate of the ethmoid bone lying under cover of the dura mater and enters the nasal cavity through the opening on the lateral side of the crista galli of the ethmoid bone. In the nose it lies in the groove on the internal surface of the nasal bone and divides into internal nasal nerves, a lateral and a medial and an external nasal nerve. The lateral branch of the internal nasal nerve supplies the mucous membrane covering the lateral wall of the nose, and the medial branch supplies the mucous membrane of the roof and the septal wall of the nasal cavity.

The external nasal nerve comes out of the nasal cavity through the opening between the lateral cartilage of the nose and the nasal bone and then passing beneath the compressor naris it supplies the skin of the ala, the apex and the vestibule of the nose.

Besides the external and internal nasal branches the nasociliary nerve gives off a communicating branch to the ciliary ganglion, and the long ciliary, the infratrochlear and the posterior ethmoidal nerves.

The maxillary nerve. The maxillary nerve is the second division of the trigeminal nerve and is entirely sensory in function.

It arises from the middle of the semilunar ganglion of the trigeminal nerve and passes horizontally forwards along the lower part of the lateral wall of the cavernous sinus and emerges out of the cranium through the foramen rotundum of the sphenoid bone. It then passes through the pterygopalatine fossa and crosses

pper part of the lateral surface of the orbital process of the palatine bone and the rior surface of the maxilla and then enters into the orbit. In the orbit it is nued as the infraorbital nerve and passes through the infraorbital groove on. loor of the orbit and then passes on to the face through the *infraorbital foramen.* ıe face it lies under cover of the lavator labii superioris and divides into terminal ıches which supply the lower eyelid, the skin and the mucous membranes of the k, and upper lip, and the skin of the side of the nose and is connected with the ıches of the facial nerve.

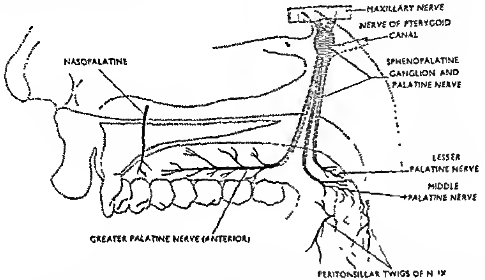


Fig. 828. The pterygopalatine (Sphenopalatine) ganglion and the palatine nerves. With kind permission from Prof W. H. Hollinshead, Ph. D., Anatomy for the Surgeons Vol. I, Paul B. Hoeber INC.

Branches:

In the cranium ..	(1) Meningeal.
Inside pterygopalatine fossa	(1) Zygomatic. (2) Ganglionic. (3) Posterior superior dental.
In the infraorbital canal	(1) Middle superior dental. (2) Anterior superior dental.
In the face ..	(1) Palpebral. (2) Nasal. (3) Labial.

Meningeal nerve. The meningeal branch of the maxillary nerve arises from it close to the semilunar ganglion of the trigeminal nerve and soon accompanies the anterior branch of the middle meningeal artery and ends by supplying the dura mater in the middle cranial fossa. It communicates with the anterior branch of the meningeal branch of the mandibular nerve (nervus spinosus).

Zygomatic nerve. It arises from the maxillary nerve in the pterygopalatine fossa and enters the orbital cavity through the inferior orbital fissure. In the orbit it passes to its lateral wall where it ends by dividing into zygomatico-facial and zygomatico-temporal branches.

The *zygomatico-facial nerve* passes through the zygomatico-facial foramen to enter into the face where it becomes superficial by piercing the orbicularis oculi and supplies the skin covering the zygomatic bone. It joins with the zygomatic branches of the facial nerve and the palpebral branches of the maxillary nerve to form a plexus.

The *zygomatico-temporal nerve* enters the temporal fossa by passing through the zygomatico-temporal foramen and ascends upwards between the temporalis muscle and the bone. It becomes superficial by piercing the temporal fascia about three-fourth inch above the zygomatic arch opposite the lateral angle of the orbit and supplies the skin of the adjoining region.

In the orbit it communicates with the lacrimal nerve by a small twig and this branch probably carries the parasympathetic (secreto-motor) fibres to the lacrimal gland from the pterygopalatine ganglion. In the temporal region it communicates with the temporal branches of the auriculotemporal and the facial nerves.

Ganglionic branches. They are usually two branches which pass to join the pterygopalatine (sphenopalatine) ganglion.

Posterior superior dental nerves. They are two in number and may arise by a common trunk. They arise from the maxillary nerve just before it enters into the infraorbital groove. It provides twigs which supply the gums and the adjoining portions of the mucous membrane of the cheek and then enter into the substance of the maxilla through the posterior superior dental canal. Within the maxilla they communicate with the middle superior dental nerve and supply the mucous membrane of the maxillary air sinus and the molar teeth.

Middle superior dental nerve. Its origin is variable and more frequently it arises from the infraorbital nerve and enters the lateral wall of the maxillary air sinus through the minute opening in the posterior part of the floor of the infraorbital canal. It supplies the two premolar teeth and forms the superior dental plexus by uniting with the anterior and posterior dental nerves.

Anterior superior dental nerve. It arises from the infraorbital nerve and passes to the anterior wall of the maxillary air sinus through a canal at the lateral and anterior part of the infraorbital canal. It supplies the incisors and the canine teeth and provides a nasal branch which enters the inferior meatus of the nose by piercing its lateral wall and supplies the mucous membrane covering the anterior part of the lateral wall and the floor of the inferior meatus. In the nasal cavity it communicates with the nasal branches of the pterygopalatine (sphenopalatine) ganglion.

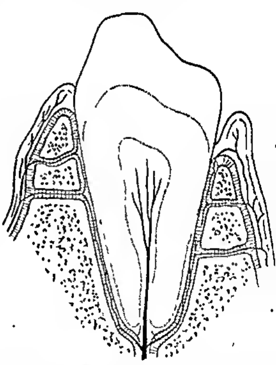


Fig. 829. A section of a tooth showing the distribution of the nerve. With kind permission from Prof. Hollinshead, Ph.D., Anatomy for the Surgeons, Vol. I, Paul B. Hoeber INC.

Palpebral branches. They ascend upwards beneath the orbicularis oculi and supply the skin and conjunctiva of the lateral part of the lower eyelid.

Nasal nerves. They supply the skin on the lateral side of the bridge of the nose and the anterior part of the nasal septum. They communicate with the external nasal branch of the anterior ethmoidal nerve.

Labial branches. They form a bunch of nerve fibres which descend downwards beneath the levator labii superioris and end by supplying the skin and the mucous

membrane on the anterior part of the cheek, the skin of the upper lip and the labial glands. They unite with the buccal branches from the facial to form a plexus, the infraorbital plexus.

The mandibular nerve. It is a mixed nerve and consists of a motor and a sensory root. The sensory root arises from the lateral part of the semilunar ganglion of the trigeminal nerve and the motor root is the continuation of the motor part of the trigeminal nerve and lies beneath the semilunar ganglion. The two roots of the nerve emerge through the foramen ovale of the sphenoid bone separately and are united together immediately below the foramen where the nerve lies in between the tensor palati muscle medially and the lateral pterygoid muscle laterally. Just below the union of the two roots the mandibular nerve gives out two branches, the meningeal (nervus spinosus) and the nerve to the medial pterygoid muscle and then divides into a smaller anterior and a larger posterior trunk.

Branches. (1) *Meningeal branch (Nervus spinosus).* It accompanies the middle meningeal artery and enters the cranial cavity through the foramen spinosum. It then divides into anterior and posterior branches which accompany the corresponding branches of the middle meningeal artery and supply the dura mater. The anterior branch communicates with the meningeal branch of the maxillary nerve and the posterior branch supplies a few twigs which pass through the fissure between the petrous and the squamous parts of the temporal bone and end by supplying the mucous membrane lining the mastoid air cells.

(2) *Nerve to the medial pterygoid.* It arises from the deep aspect of the undivided mandibular nerve and soon enters into the deep surface of the medial pterygoid muscle. It provides one or two twigs to the otic ganglion to which it is intimately related.

(3) **The anterior trunk.** The smaller anterior trunk of the mandibular nerve soon divides into buccal, masseteric, deep temporal and nerve to the lateral pterygoid branches.

Buccal nerve (Buccinator nerve). It soon passes forwards between the two heads of the lateral pterygoid muscle and then runs downwards and forwards beneath the lower part of the temporalis muscle and finally descends on the superficial aspect of the buccinator muscle from under cover of the ramus of the mandible and the anterior border of the masseter muscle. On the buccinator muscle it joins with the buccal branches of the facial nerve to form the buccal plexus and supplies the skin covering the buccinator muscle and the mucous membrane covering the inner aspect of the same and the posterior part of the buccal surface of the gums.

Masseteric nerve. The masseteric nerve passes laterally through the posterior part of the mandibular notch and soon ramifies on the deep surface of the masseter muscle and also it provides branches to the mandibular joint.

Deep temporal nerves. The deep temporal branches are usually two in number, anterior and posterior. They ascend upwards from under cover of the upper border of the lateral pterygoid muscle and soon enter into the deep surface of the temporalis muscle. The anterior branch may occasionally arise from the buccal nerve and the posterior branch may also arise from the masseteric nerve.

Nerve to the lateral pterygoid muscle. The nerve to the lateral pterygoid soon passes to the deep surface of the lateral pterygoid muscle. It may arise by a common trunk with the buccal nerve.

(4) **The posterior trunk of the mandibular nerve.** The larger posterior trunk of the mandibular nerve divides into auriculotemporal, inferior dental and lingual branches.

The *auriculotemporal nerve.* The auriculotemporal nerve is entirely sensory in function and arises by two roots which encircle the middle meningeal artery and then unites to form the nerve trunk. It passes backwards on the tensor palati muscle deep to the lateral pterygoid and then passing posterior to the mandibular joint it

reaches the interval between the joint and the auricle and then reaches the superior surface of the parotid gland. It then ascends over the posterior part of the zygomatic arch behind the superficial temporal vessels and finally ends by dividing into superficial temporal branches. The following are the branches of the auriculotemporal nerve.

Branches of communication. The communicating branches join the facial nerve and the otic ganglion. The branches to the facial nerve are two in number and join the same at the posterior border of the masseter muscle. Each of its roots receive a branch from the otic ganglion through which it receives fibres from the tympanic branch of the glossopharyngeal nerve and these fibres are destined to the parotid gland supplying secreto-motor fibres to it.

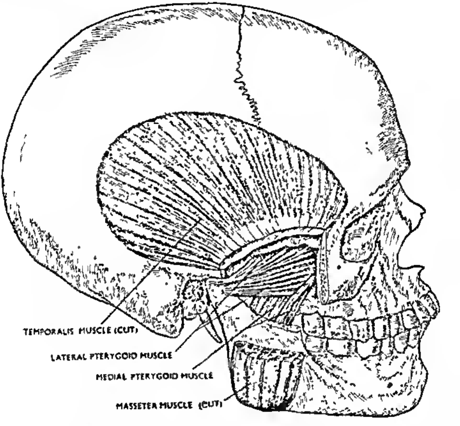


Fig. 830. The muscles of mastication supplied by the mandibular nerve. The zygomatic arch and a portion of the masseter muscle have been removed.

Auricular branches. They are two in number and supply the skin covering the helix and the tragus at the upper part of the auricle.

Branches to the external auditory meatus. They are two in number and reach the external auditory meatus by passing between the bony and the cartilaginous parts of the external auditory meatus. They supply the skin of the external auditory meatus and the tympanic membrane.

Parotid branches. They supply the secreto-motor fibres to the parotid gland and their fibres are originally derived from the glossopharyngeal nerve. The glossopharyngeal nerve through its tympanic branches forms the tympanic plexus with the caroticotympanic nerve within the tympanic cavity. The tympanic plexus gives out the lesser superficial petrosal nerve which joins the otic ganglion carrying the same fibres. The otic ganglion by its communicating branches conveys the same

fibres to the auriculotemporal nerve and the latter by its parotid branches supplies the same.

Articular branches. They are one or two branches which supply the mandibular joint.

Superficial temporal branches. They accompany the superficial temporal vessels and supply the skin of the temporal region. They communicate with the zygomatico-temporal and the facial nerves.

The inferior dental. The inferior dental nerve passes down under cover of the lateral pterygoid muscle and superficial to the sphenomandibular ligament and the medial pterygoid muscle and accompanying the inferior dental vessels it enters the mandibular canal through the mandibular foramen. Before it enters the foramen it gives out its mylohyoid branch. Within the canal it ends by dividing into incisive and mental branches. The mylohyoid nerve supplies the mylohyoid muscle and the anterior belly of the digastric muscle; the incisive branch supplies the incisors and the canine tooth of the mandible and the mucous membranes in this region. The mental branch supplies the skin opposite the symphysis menti and skin of the lower lip and the mucous membranes of the same. It also provides branches to the molar and the premolar teeth of the mandible.

The lingual nerve. The lingual nerve is the sensory nerve for the mucous membrane of the anterior two-thirds of the tongue, for the mandibular gums and the mucous membranes of the floor of the mouth.

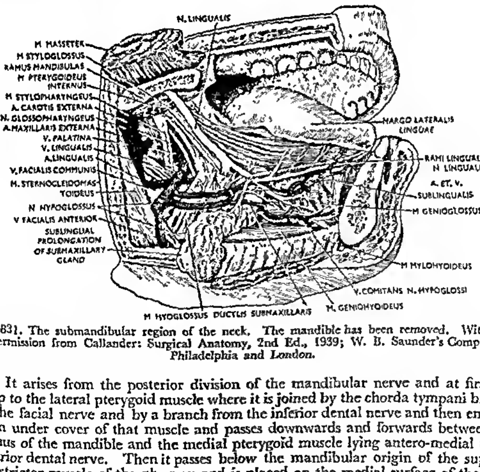


Fig. 831. The submandibular region of the neck. The mandible has been removed. With kind permission from Callander: Surgical Anatomy, 2nd Ed., 1939; W. B. Saunder's Company, Philadelphia and London.

It arises from the posterior division of the mandibular nerve and at first lies deep to the lateral pterygoid muscle where it is joined by the chorda tympani branch of the facial nerve and by a branch from the inferior dental nerve and then emerges from under cover of that muscle and passes downwards and forwards between the ramus of the mandible and the medial pterygoid muscle lying antero-medial to the inferior dental nerve. Then it passes below the mandibular origin of the superior constrictor muscle of the pharynx and is placed on the medial surface of the body of the mandible opposite the third molar tooth where it is covered only by the mucous membrane. Then it crosses the styloglossus muscle and passes forwards in between the mylohyoid and the hyoglossus muscles. In this situation it is placed

above the hypoglossal nerve and the deep part of the submandibular gland and its duct. Then it runs from above downwards and forwards and at first lies on the lateral side of the submandibular duct and then winding round below it, passes forwards on its medial side. Finally it crosses the lateral surface of the genioglossus muscle and breaks into its terminal branches which lie immediately beneath the mucous membrane. Its terminal filaments join with the branches from the hypoglossal nerve at the tip of the tongue

It sends communicating branches to the submandibular ganglion and forms loops of communication with the hypoglossal nerve; it is joined by the chorda tympani nerve and by the communicating branch from the inferior dental nerve.

Ganglia associated with the branches of the trigeminal nerve.

Pterygopalatine (Sphenolpalatine) ganglion. It is the largest of the ganglia associated with the branches of the trigeminal nerve. It is connected with the maxillary division of the trigeminal nerve and lies within the pterygopalatine fossa.

Shape. Triangular.

Size. It measures about 1/5 inch in diameter opposite its base.

Position. It is situated in the upper part of the pterygopalatine fossa opposite the pterygoid canal and is suspended from the maxillary nerve by two roots.

Roots. Motor and sympathetic. The pterygoid nerve formed by the union of the greater (superficial) petrosal branch of the facial nerve and the deep petrosal nerve from carotid plexus of sympathetic, constitutes its motor and sympathetic roots. The nerve of the pterygoid canal also carries some parasympathetic fibres to the ganglion from the facial via its greater (superficial) petrosal branch.

Sensory root. These fibres are derived from the maxillary nerve and are joined to the ganglion by two roots which suspend the ganglion from the nerve.

Branches:

(1) *Orbital.* They consist of two or three filaments which enter the orbit through the inferior orbital fissure and supply motor filaments to the orbitalis muscle, secreto-motor fibres to the lacrimal gland (parasympathetic fibres) and sensory fibre to the periosteum of the orbit, to the sphenoidal and ethmoidal air sinuses which pass through the posterior ethmoidal canal.

(2) *Palatine.* They are distributed to the mucous membranes of the roof of the mouth, soft palate, tonsils and the lining membrane of the nasal cavity as greater and lesser palatine nerves.

(3) *Nasal.* They are the long and short nasopalatine (sphenopalatine) nerves and supply the mucous membranes of the nasal septum and the nasal cavity.

(4) *Pharyngeal.* They supply the mucous membranes of the nasal part of the pharynx behind the auditory (pharyngotympanic) tube.

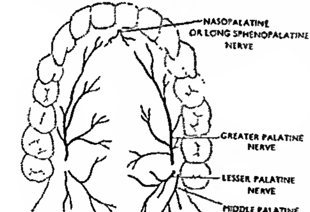


Fig. 832. The innervation of the hard and the soft palate. With kind permission from Prof. W. H. Hollinshead, Ph. D., Anatomy for the Surgeons: Vol. I, Paul B. Hoeber INC.

Otic ganglion. It is connected with the mandibular division of the trigeminal nerve.

Shape and size. It resembles a pin's head in size and reddish in colour.

Position. It lies on the medial side of the mandibular nerve at the base of the skull immediately below the foramen ovale.

Relations:

Anteriorly—Medial Pterygoid muscle.
Posteriorly—Middle meningeal artery.
Laterally —Mandibular nerve.
Medially —Tensor palati muscle.

Roots:

Motor or parasympathetic. The lesser (superficial) petrosal nerve from the tympanic branch of the glossopharyngeal nerve constitutes its motor or parasympathetic root. The lesser (superficial) petrosal nerve also receives some fibres from the facial nerve. By communicating branches to the auriculotemporal nerve it supplies secreto-motor fibres to the parotid gland through auriculotemporal nerve.

Sympathetic root. These fibres are derived from the sympathetic plexus around the middle meningeal artery. These fibres pass to the auriculotemporal nerve through its communicating branch and are distributed to the blood vessels of the parotid gland through the same nerve.

Branches:

Motor branches. They supply the two tensors, the tensor palati and the tensor tympani muscles. These branches are not true branches from the ganglion but these are the fibres from the nerve to the medial pterygoid muscle which pass through this ganglion uninterrupted.

Secreto-motor branches. They join auriculotemporal nerve and supply secretory fibres to the parotid gland. These fibres are derived from the tympanic branch of the glossopharyngeal nerve.

Communications:

(*a*) To auriculotemporal nerve.
(*b*) To chorda tympani nerve.
(*c*) To pterygoid nerve.

Submandibular ganglion. It is attached to the lingual branch of the mandibular nerve.

Shape and size. It resembles a pin's head in size.

Situation. It is suspended from the lingual nerve by two roots and lies on the outer surface of the hyoglossus muscle.

Relations:

Medially —Hyoglossus muscle.
Laterally —Submandibular gland.
Superiorly—Lingual nerve.
Inferiorly —Hypoglossal nerve.

Roots. Secreto-motor (parasympathetic fibres). These fibres are derived from the chorda tympani branch of the facial nerve.

Sensory roots. They are derived from the lingual branch of the mandibular nerve.

Sympathetic root. They are derived from the sympathetic plexus of nerves around the facial artery.

Branches:

(1) *Secreto-motor branches.* They supply the submandibular and sublingual glands.

(2) *Sensory branches.* They supply sensory fibres to the mucous membranes of the mouth and tongue through the lingual nerve.

Ciliary ganglion. It is a small reddish ganglion associated with the nerve to the inferior oblique branch of the oculomotor nerve.

Shape and size. It resembles a pin's head in size.

Situation. It lies in the fat between the optic nerve medially and the rectus lateralis laterally at the apex of the orbital cavity.

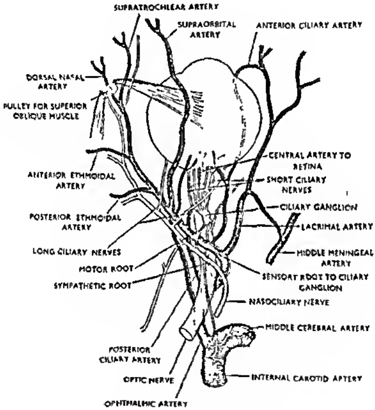


Fig. 833. The ciliary ganglion and the ciliary nerves.

Roots. Motor. It is derived from the branch of the oculomotor nerve supplying the inferior oblique muscle of the eye-ball. It carries preganglionic parasympathetic fibres (parasympathetic root) which are believed to arise from the Edinger-Westphal nucleus. The postganglionic fibres from the ciliary ganglion run along with the short ciliary nerves and supply the sphincter pupillae and the ciliaris muscles.

Sensory. It is derived from the nasociliary nerve.

Sympathetic. It is derived from the sympathetic plexus around the ophthalmic artery. These are postganglionic sympathetic fibres from the superior cervical sympathetic ganglion and they pass through the ciliary ganglion uninterruptedly and supply the dilator pupillae.

Branches:

Motor branches. They are short ciliary nerves which consist of about 15 to 20 short branches. They supply the ciliary body and the circular fibres of the iris (constrictor pupillae) and derive fibres from the oculomotor nerve. They also supply the radial fibres of the iris (dilator pupillae) and the fibres are derived from the sympathetic root.

Sensory branches. They are distributed to the iris, cornea, sclera and the choroid.

THE ABDUCENT NERVE

It is the sixth cranial nerve and is entirely motor in function. It supplies the rectus lateralis muscle of the eye-ball.

Deep origin. It arises from the abducent nerve nucleus situated at the floor of the fourth ventricle beneath the colliculus facialis.

Morphologically it contains somatic motor fibres.

Superficial origin. It leaves the brain from the furrow between the lower border of the pons and the upper end of the pyramid of the medulla oblongata.

Course and relation. From its origin in the brain stem it passes upwards, forwards and laterally through the cisterna pontis and pierces the inner layer of the dura mater lateral to the dorsum sellae of the sphenoid and passes beneath the petro-sphenoidal ligament to enter into the cavernous sinus. In the cavernous sinus it at first lies lateral to the internal carotid artery and then infero-lateral to it. It then enters the orbit through the medial part of the superior orbital fissure and passing through the common tendineus ring it enters the medial surface of the rectus lateralis muscle to supply it.

Connections. (1) It is connected with the pyramidal fibres of the opposite side; (2) with the third, fourth and eighth cranial nerves by the medial longitudinal bundle; (3) with the visual cortex by the tectobulbar tract.

Communications. It communicates with the internal carotid plexus of sympathetics and the ophthalmic division of the trigeminal nerve.

Paralysis of the abducent nerve:

Effects. (1) Paralysis of the rectus lateralis of the same side results in convergent strabismus with consequent diplopia and there is inability to move the eye-ball laterally.

(2) There may be paralysis of the medial rectus of the opposite side resulting in conjugate diviation of the eye-ball in which both the eye-balls are turned to the same direction. Paralysis of the medial rectus of the opposite side can be explained by the fact that the nerve supplying the same muscle has its origin in the abducent nerve nucleus of the opposite side and after its origin it passes along with the third nerve. So when there is associated conjugate deviation it indicates the nuclear lesion.

THE FACIAL NERVE

The facial nerve is a mixed nerve and consists of a motor and a sensory root. They unite at the bottom of the internal acoustic (auditory) meatus.

Deep origin. (Motor root). The motor root fibres have two sources of origin, some fibres arise from a nucleus (branchial motor nucleus) in the reticular formation of the lower part of the pons and others from the superior salivary nucleus (visceral motor nucleus) situated in the reticular formation. The motor nerve nuclei are connected with the pyramidal tract fibres.

Morphologically the fibres of the facial nerve contains branchial motor, visceral motor and taste fibres.

Sensory root. These fibres originate in the facial ganglion (geniculate ganglion) of the facial nerve where the fibres from the unipolar nerve cells divide into central and peripheral groups. The central group of fibres unite to form the sensory root which closely accompanies the motor root and enters the brain stem at the superficial origin of the facial nerve and ends in the sensory nucleus, the nucleus of the tractus solitarius of the medulla oblongata. The sensory nucleus is connected with the hippocampal gyrus in the region of the uncus.

The sensory root contains taste fibres and preganglionic parasympathetic fibres (secretomotor fibres) for the submandibular and sublingual salivary glands and for the lacrimal gland.

Superficial origin. The two roots of the nerve are attached to the brain stem at a point between the olive and the inferior cerebellar peduncle.

Intrapetrous part. Course and relation. The two roots of the facial nerve from their attachment to the brain stem pass to the internal auditory meatus where the motor root lies superficial to the sensory root and the auditory nerve. At the bottom of the meatus the two roots unite to form a single trunk and enters the facial canal. In the canal it first passes laterally above the vestibule and reaches the medial wall of the tympanic cavity from where it curves abruptly backwards forming a bend (genu) and runs on the medial wall of the epitympanic recess for about 1/4 inch and then turns downwards forming a second bend or genu on the posterior wall of the tympanic cavity. Then it emerges out of the temporal bone through the stylomastoid foramen. As it passes backwards from the medial wall of the cavity to the medial wall of the epitympanic recess it lies below the lateral semicircular canal and above the promontory, fenestra vestibuli and the fenestra cochlea.

About 6 mm. above the stylomastoid foramen it gives out its chorda tympani branch. As it descends on the posterior wall of the tympanic cavity it gives a branch to the stapedius muscle.

From stylomastoid foramen to the face. After its exit from the stylomastoid foramen it crosses the styloid process and the external carotid artery and then enters into parotid gland and divides primarily into two branches from which five branches are given out which emerge into the face under cover of the antero-medial surface of the gland.

Communications:

In the internal auditory meatus. With the stato-acoustic (auditory) nerve.

At the facial ganglion. (*a*) With the pterygopalatine ganglion by the greater (superficial) petrosal nerve. (*b*) With the otic ganglion by a branch which joins the lesser (superficial) petrosal nerve. (*c*) With the sympathetic ganglion on the middle meningeal artery.

In the facial canal. With the auricular branch of the vagus nerve.

At its exit from the stylomastoid foramen. With the glossopharyngeal, vagus, great auricular, and auriculotemporal nerves.

On the face. With the branches from the trigeminal nerve.

Behind the ear. With the lesser occipital nerve.

In the neck. With the anterior cutaneous cervical nerve.

Branches:

Within the facial canal. (1) Nerve to the stapedius muscle. (2) Chorda tympani.

At its exit from the stylomastoid foramen. (1) Posterior auricular. (2) Digastric (Posterior belly). (3) Stylohyoid.

On the face. (1) Temporal. (2) Zygomatic. (3) Buccal. (4) Mandibular. (5) Cervical.

Nerve to the stapedius. It arises from the facial nerve within the tympanic cavity opposite the pyramid on the posterior wall of the tympanic cavity and runs forwards in a canal to reach the muscle.

Chorda tympani nerve. It arises from the facial nerve as it traverses through the posterior wall of the tympanic cavity and enters the tympanic cavity through an opening, the posterior canaliculus for the chorda tympani nerve which is situated on the posterior wall of the tympanic cavity about one-fourth inch above the stylomastoid foramen and corresponds to the level of the upper end of the manubrium of the malleus. It then runs forwards between the mucous and the fibrous layers of the tympanic membrane and crosses the manubrium of the malleus. It then comes out of the tympanic cavity through the anterior canaliculus for the chorda tympani nerve situated at the inner end of the petrotympanic fissure. After its exit it lies in a groove on the medial aspect of the spine of the sphenoid and runs downwards and forwards deep to the lateral pterygoid muscle. In this part of its course it lies on the lateral side of the tensor palati muscle and crosses the middle meningeal artery, roots of the auriculotemporal nerve and the inferior dental vessels and nerve. It then joins the posterior border of the lingual nerve at an acute angle. Through the lingual nerve it supplies taste fibres to the anterior two-thirds of the tongue and sends out parasympathetic root to the submandibular ganglion through which it supplies secreto-motor fibres to the submandibular and the sublingual salivary glands. Before it joins the lingual nerve it receives a communicating branch from the otic ganglion.

The taste fibres from the facial nerve. They reach the nucleus of the tractus solitarius (nucleus for taste) by two routes. From the anterior two-thirds of the tongue they run along with the lingual nerve to the chorda tympani nerve, then to the geniculate ganglion and sensory root of facial nerve and finally reach the nucleus of the tractus solitarius. The taste fibres from the soft palate pass along the greater and lesser palatine nerves to the pterygopalatine ganglion, then to the pterygoid nerve, greater petrosal nerve, geniculate ganglion and sensory root and finally reach the nucleus of the tractus solitarius.

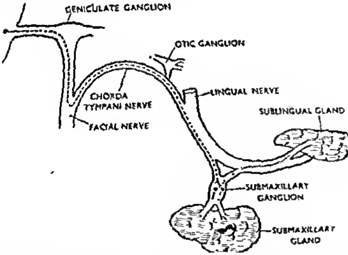


Fig. 834. The innervation of the submandibular and sublingual salivary glands. With kind permission from Prof. W. H. Hollinshead, Ph.D., Anatomy for the Surgeons, Vol. I, Paul B. Hoeber INC.

The secreto-motor fibres from the facial nerve. The fibres from the submandibular and sublingual salivary glands follow the taste fibres to the superior salivary nucleus. Those from the lacrimal gland pass along with the lacrimal nerve, zygomaticotemporal nerve, orbital branch of pterygopalatine ganglion, pterygoid nerve, greater petrosal nerve and along the geniculate ganglion and the sensory root to the superior salivary nucleus (uncertain).

Posterior auricular nerve. It arises from the facial nerve at the stylomastoid foramen and ascends upwards over the mastoid process of the temporal bone and then divides into auricular and occipital branches. The auricular branch supplies the auricularis posterior and the intrinsic muscles on the back of the auricle. The occipital branch ascends upwards and backwards as far as the superior nuchal line and supplies the occipital belly of the occipito-frontalis.

Below the stylomastoid foramen it communicates with the auricular branch of the vagus, the posterior branch of the great auricular and the lesser occipital nerves.

Digastric branch. It arises from the facial nerve at the stylomastoid foramen and running downwards and forwards for a short course breaks up into branches which enter the posterior belly of the digastric. One of its filaments communicates with the glossopharyngeal nerve.

Stylohyoid branch. It also arises at the stylomastoid foramen either separately or in common with the digastric branch and soon enters the stylohyoid muscle at its middle part.

Temporal branches. They come out of the upper part of the parotid gland and ascend upwards in front of the superficial temporal vessels by crossing the zygomatic arch. They supply the intrinsic muscles at the antero-lateral aspect of the auricle, the orbicularis oculi, the corrugator and the frontal belly of the occipito-frontalis.

They communicate with the auriculotemporal, zygomaticotemporal and the lacrimal and the supraorbital nerves.

Zygomatic branches. They run upwards and forwards to the lateral angle of the eye and supply the orbicularis oculi. They communicate with lacrimal and the zygomaticofacial nerves.

Buccal branches. They are arranged into superficial and deep branches. The superficial branches run forwards beneath the skin and supply the superficial muscles of the face and join with the infratrochlear and the external nasal nerves. The deep branches run forwards beneath the zygomaticus major and the levator labii superioris and join with the infraorbital nerve to form the infraorbital plexus. They supply the buccinator, zygomaticus major et minor, levator labii superioris, levator labii superioris alaeque nasi, leavator anguli oris and the orbicularis oris.

Mandibular branches. They run forwards below the angle of the mandible under cover of the platysma and pass across the superficial aspect of the digastric triangle. Then they pass upwards and forwards crossing the body of the mandible and reach the deep aspect of the depressor anguli oris. They communicate with mental nerves and supply the muscles of the lower lip.

Cervical branch. It leaves the lower part of the parotid gland and enters the neck where it runs downwards and forwards under cover of the platysma to the front of the neck and communicates with the anterior cutaneous branches of the cervical plexus and supplies the platysma muscle.

Paralysis of the facial nerve. It would be interesting to note how symptomatic manifestations differ when the facial nerve is paralysed due to diseases or injury at different levels during its course. . The following manifestations have been noted when the nerve is injured at different levels.

(1) *If the lesion is supranuclear.* When the connecting pyramidal tract fibres are injured there is paralysis of the muscles of the lower part of the face of the opposite side.

There is always associated hemiplegia. The muscles of the upper face and the forehead escape because the facial nerve nucleus has bilateral connections from the pyramidal fibres.

(2) *If the lesion is in the facial nerve nucleus.* There is complete paralysis of the same half of the face with the exception of the orbicularis oris. The latter muscle escapes because the nerve supplying this muscle has its nuclear origin from the

hypoglossal nerve and not from the facial nerve. After its origin from the hypoglossal nerve nucleus it joins the nuclear fibres of the facial nerve.

(3) *If the lesion is in the pons.* There is complete paralysis of the same half of the face but the taste and hearing are not affected. There may be associated paralysis of the abducent nerve because the facial nerve fibres during its course ascend over the abducent nerve nucleus forming colliculus facialis in the floor of the fourth ventricle.

(4) *If the lesion is in the petrous portion of the temporal bone.* In this sensory fibres are also affected and in addition to the paralysis of the same half of the face there will be loss of taste in the anterior 2/3 of the tongue (patient cannot distinguish between bitter and sweet, acid and salt). There is associated paralysis of the stapedius muscles and hearing accuracy is lost.

(5) *If the nerve is affected at its exit from the stylomastoid foramen* (Bell's palsy). There is complete paralysis of the same half of the face. The taste fibres are not affected because the chorda tympani nerve has already left the nerve about one-fourth inch above the stylomastoid foramen.

THE STATO-ACOUSTIC (AUDITORY) NERVE

The stato-acoustic (auditory) nerve is the eighth cranial nerve and is entirely sensory in function. It consists of two distinct divisions, cochlear and vestibular divisions. The cochlear division is the nerve of hearing whereas the vestibular division is the nerve of equilibrium.

The two divisions of the nerve are attached to the brain stem in the transverse fissure between the pons and the medulla immediately in front of the inferior cerebellar peduncle and behind the facial nerve (superficial origin).

Cochlear nerve and the auditory path. The central processes of the bipolar cells of the spiral ganglion constitute the cochlear nerve and its peripheral processes are distributed in the organ of corti of the internal ear. From its origin, the cochlear nerve passes through the internal acoustic (auditory) meatus along with the vestibular nerve and enters the medulla oblongata through the transverse fissure between the pons and the medulla immediately in front of the inferior cerebellar peduncle. In the medulla most of its fibres end in the ventral and dorsal cochlear nuclei.

The fibres from the ventral cochlear nucleus ascend upwards in the pons where they partially decussate with the fellow of the opposite side like the optic nerve and then diverge from each other to form a transverse band of fibres within the central part of the pons known as the corpus trapezoideum.

The fibres from the dorsal cochlear nucleus pass medially across the vestibular area and medial eminence on the floor of the fourth ventricle to reach the median sulcus and form the auditory striae in this situation. They then decussate with the fellow of the opposite side in the median plane and ascend upwards in the pons to join the corpus trapezoideum.

The upward continuation of the fibres of the corpus trapezoideum form the lateral lemniscus which passes through the tegmentum of the mid-brain and finally end in the inferior quadrigeminal body and the medial geniculate body. Relay fibres from here pass through the posterior part of the internal capsule *behind* the optic radiation fibres and end into the audito-sensory area on the temporal lobe of the brain (Transverse temporal gyri and the superior temporal gyrus).

N.B. Sound vibrations after being received by the external ear are propagated to the drum which vibrates and transmits the same vibrations through the auditory ossicles to the fenestra vestibuli where the base of the stapes by its oscilating movement sets up an intensified vibration in the endolymph and perilymph of the internal ear. The fluid vibration causes rubbing or friction between basilar membrane and a nerve impulse is generated which subsequently passed through the ramifications of the cochlear nerve in the organ of corti and travel through it to the brain as stated above.

Vestibular division of the auditory nerve. The vestibular division of the auditory nerve is the nerve of equilibrium and forms the central processes of the vestibular ganglion situated at the bottom of the internal auditory meatus. The peripheral processes of the ganglion are distributed to the saccule, utricle and to the semicircular canals of the internal ear. The vestibular nerve enters the brain stem at the superficial origin of the auditory nerve and lies medial to the cochlear nerve.

The vestibular nerve from its superficial origin passes backwards through the pons between the spinal tract of the trigeminal nerve and the inferior cerebellar peduncle and then divides into ascending and descending branches which end into superior, inferior, medial and lateral vestibular nuclei. The lateral, medial and the inferior vestibular nuclei lie in close relation to one another opposite the vestibular area on the floor of the fourth ventricle whereas the superior nucleus extends into the pons.

The efferents from the vestibular nuclei pass in four directions to establish vestibular connections with different parts of the body through different tracts which are as follows:

(1) Vestibulo-cerebellar tract. By means of this tract the vestibular apparatus is connected with the cerebellum.

(2) Medial longitudinal bundle. By means of this it is connected with the nuclei of the third, fourth, sixth and the eleventh cranial nerves.

(3) Vestibulo-spinal tract. By this the vestibular apparatus is connected with the anterior horn cells of the spinal nerves.

(4) Fibres which join the corpus trapezoideum pass to the inferior quadrigeminal body through the lateral lemniscus.

THE GLOSSOPHARYNGEAL NERVE

It is the ninth cranial nerve and contains both sensory and motor fibres. It supplies secreto-motor fibres to the parotid gland, motor fibres to the stylopharyngeus muscle, sensory fibres to the tonsils and pharynx and sensory and taste fibres to the posterior one-third of the tongue.

Superficial origin. It forms three rootlets which are attached to the groove between the olive and the inferior cerebellar peduncle.

Deep origin. The motor fibres of the glossopharyngeal nerve arise from the upper part of the nucleus ambiguus situated within the reticular formation of the medulla oblongata.

Morphologically the glossopharyngeal nerve consists of branchial motor, visceral motor, visceral sensory and taste fibres. The nucleus for the branchial motor fibres supplying the stylopharyngeus muscle is represented in the upper part of the nucleus ambiguus. The nucleus for the visceral motor fibres (secreto-motor) supplying secretory fibres to the parotid gland is the inferior salivary nucleus whereas the nucleus for the taste fibres is the nucleus of the tractus solitarius. The nucleus for the visceral sensory fibres is probably represented by the sensory nuclei of the trigeminal nerve.

Its sensory fibres form the central processes of the unipolar cells of the superior and inferior ganglia of the nerve, which enter the brain stem at the superficial origin of the nerve and end into nucleus of the tractus solitarius (concerned with taste) and into the sensory nuclei of the trigeminal or dorsal nucleus of the vagus nerve (concerned with general sensations).

The glossopharyngeal nerve emerges on to the neck through the central part of the jugular foramen, antero-lateral to the vagus and accessory nerves. (In its transit to the jugular foramen it is lodged in the triangular depression on the inferior surface of the petrous part of the temporal bone). Then it runs forwards between the internal jugular vein and the internal carotid artery; then it descends downwards and forwards in front of the internal carotid artery and behind the styloid process and the styloid group of muscles (stylo-hyoid, stylo-glossus and stylo-pharyngeus)

to reach the posterior border of the stylopharyngeus muscle. It then curves forwards, lying in front of the stylopharyngeus muscle to which it supplies and then passes in between the superior and middle constrictor muscles of the pharynx and finally breaks up into branches to be distributed to the tonsil, mucous membranes of the pharynx and the posterior part of the tongue and the mucous glands of the mouth.

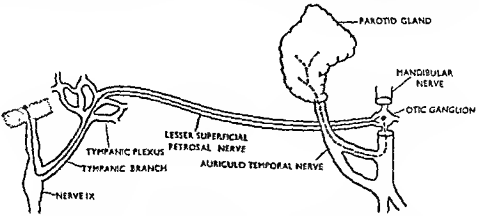


Fig. 835. The secreto-motor supply of the parotid gland. With kind permission from Prof Hollinshead: Anatomy for the Surgeons, Vol. 1, Paul B. Hoeber INC.

Branches:

(1) *Tympanic.* It passes into the tympanic cavity through an opening on the ridge between the carotid opening and the jugular fossa of the temporal bone and forms the tympanic plexus with the carotico-tympanic nerves from the carotid plexus of sympathetic in the tympanic cavity and supplies the mucous membrane of the same and gives origin to the lesser superficial petrosal nerve and supplies communicating branch to the greater (superficial) petrosal nerve. The lesser (superficial) petrosal nerve joins the otic ganglion and from there its fibres are communicated to the auriculotemporal nerve and through auriculotemporal nerve it supplies secreto-motor fibres to the parotid gland.

(2) *Pharyngeal branch.* The pharyngeal branch joins with the pharyngeal branches of the vagus and sympathetics and with the external laryngeal nerve to form the pharyngeal plexus. Through the pharyngeal plexus it supplies sensory filaments to the mucous membrane of the pharynx.

(3) *Carotid branches.* These are communicating with the pharyngeal branch of the vagus and the sympathetics to be distributed to the carotid sinus and carotid body.

(4) *Muscular.* This is the only muscular branch given by the glossopharyngeal nerve which supplies the stylopharyngeus muscle.

(5) *Tonsillar.* It forms the tonsillar plexus with the lesser palatine nerve and supplies sensory filaments to the tonsil, soft palate and oropharyngeal isthmus.

(6) *Lingual.* Two in number. They supply the vallate papillae and the mucous membrane of the posterior one-third of the tongue. It is the nerve of both general sensation and taste.

THE VAGUS NERVE

The vagus nerve is the tenth cranial nerve and consists of both motor and sensory fibres.

Superficial origin. It is attached to the brain stem immediately below the glossopharyngeal nerve and lies in between the inferior cerebellar peduncle and the olive.

Deep origin. The motor fibres of the nerve take their origin from the dorsal nucleus (mixed nucleus) of the vagus situated opposite the vagal triangle in the floor

of the fourth ventricle and also from the nucleus ambiguus. The motor fibres from the dorsal nucleus supply visceral efferent fibres to the bronchial muscles, the heart, oesophagus, stomach, small intestine and part of the large intestine. The motor fibres which arise from the nucleus ambiguus supply the cricothyroid, the muscles of the pharynx and larynx.

The sensory fibres of the vagus nerve arise from the superior and inferior ganglia of the nerve and enter the medulla at the superficial origin of the nerve and end in the dorsal nucleus and carry visceral afferent fibres from all the viscera to which it supplies visceral efferent fibres, that is, from the larynx, pharynx, bronchi, lungs, heart, oesophagus, stomach and small intestine. The nucleus of the tractus solitarius receives taste fibres from the taste-buds on both surfaces of the epiglottis and from the valleculae of the tongue through internal laryngeal nerve.

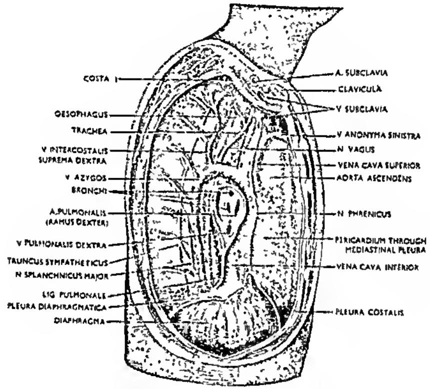


Fig. 836. The thoracic cavity seen from the right side. The lung has been removed. Note the position of the azygos vein and the vagus nerve in relation to the root of the lung. With kind permission from Callander: Surgical Anatomy, 2nd Ed., 1939; W. B. Saunder's Company: Philadelphia and London

Course and relation. From its superficial origin the vagus nerve passes laterally over the tuberculum jugulare of occipital bone to reach the intermediate compartment of the jugular foramen and lies behind the glossopharyngeal nerve and in front of the accessory nerve.

At the jugular foramen it forms a ganglion, the *superior ganglion of the vagus,* and then as it comes out through the jugular foramen it forms another ganglion, the *inferior ganglion of the vagus.* From the lower end of the inferior ganglion it descends vertically downwards up to the root of the neck.

Opposite the carotid triangle it is contained within the carotid sheath where it is placed posteriorly in between the common carotid artery and the internal jugular vein. From the root of the neck the course and relations of the nerve vary on the two sides.

On the right side it crosses in front of the first part of the subclavian artery behind the internal jugular vein and enters the thorax through its inlet. Then it descends downwards through the superior mediastinum behind the brachiocephalic vein to reach the postero-medial aspect of the superior vena cava where it lies to the right of the superior vena cava and the terminal portion of the trachea. Then it crosses behind the right bronchus to reach the posterior aspect of the root of the lungs where it breaks up into branches which with filaments from the second, the third and the fourth thoracic ganglia form the right posterior pulmonary plexus. Then it descends as three or four branches from the lower end of the plexus to the posterior aspect of the oesophagus where it forms the posterior part of the oesophageal plexus with branches from the left vagus nerve. Descending further downwards its fibres are reunited to form a nerve trunk, the *posterior vagal trunk* which enters the abdomen through the oesophageal opening in the diaphragm and then breaks up into gastric and coeliac branches.

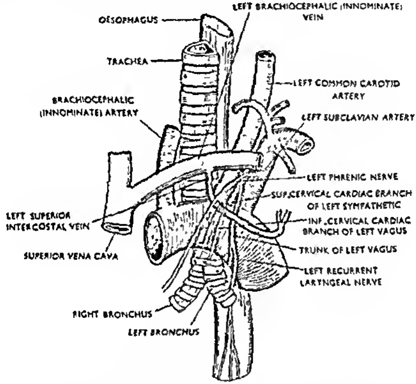


Fig. 837. The arch of the aorta and some of its relations.

On the left side it enters the thorax between the left common carotid and the eft subsclavian artery and behind the left brachiocephalic vein. Then it crosses in ront of the arch of the aorta where it is crossed superficially by the left phrenic nerve ınd by the left superior intercostal vein. Then it passes posterior to the root of the ung where it forms the left posterior pulmonary plexus like that on the right side and lescends on the anterior part of the oesophagus and forms the anterior part of the esophageal plexus with the right vagus nerve. Descending further downwards its ibres are reunited to form a trunk, the anterior vagal trunk, which enters the abdomen through the oesophageal opening in the diaphragm and then divides into branches which supply the stomach, duodenum, head of the pancreas, and the porta hepatis.

Branches of the vagus nerve:

At the jugular fossa:

Auricular.
Meningeal.

In the neck:

Pharyngeal.
Superior laryngeal.
Branches to the carotid body.
Right recurrent laryngeal.
Cardiac.

Within the thorax:

Left recurrent laryngeal.
Cardiac.
Pulmonary.
Oesophageal.

Within the abdomen:

Coeliac.
Gastric.
Hepatic.

Auricular branch. The auricular branch arises from the superior ganglion of the vagus nerve in the jugular foramen and is soon joined by a small filament from the inferior ganglion of the glossopharyngeal nerve. It then passes behind the internal jugular vein to the lateral wall of the jugular fossa where it enters the mastoid canaliculus and then runs through the substance of the temporal bone. In its course through the bone it crosses the facial canal at a point about 1/6 inch above the stylomastoid foramen where it gives out an ascending branch which joins the facial nerve. It comes out of the temporal bone through the tympanomastoid fissure and then divides into two branches, one joins the posterior auricular nerve and the other supplies the part of the skin of the posterior aspect of the auricle, the external auditory meatus and the external aspect of the tympanic membrane.

Meningeal branch. It also arises from the superior ganglion of the vagus nerve and supplies the dura mater in the posterior cranial fossa.

Pharyngeal. The pharyngeal branch arises from the upper part of the inferior ganglion of the vagus nerve and consists of fibres derived from the cranial root of the accessory nerve. It descends downwards between the external and internal carotid arteries to the upper border of the middle constrictor muscle of the pharynx where it breaks up into numerous branches which join with the pharyngeal branch of the glossopharyngeal, external laryngeal and branches from the sympathetic to form the pharyngeal plexus. Through this plexus it supplies all the muscles of the pharynx and all the muscles of the soft palate except the tensor palati. One minute filament from this joins the hypoglossal nerve as it hooks round the occipital artery and is known as the ramus lingualis vagi.

Superior laryngeal nerve. It arises from the middle of the inferior ganglion of the vagus nerve and receives its motor fibres from the accessory nerve. From its origin it runs obliquely downwards and medially behind the internal carotid artery to the upper part of the thyroid cartilage. It ends by dividing into two unequal parts, a larger internal and a smaller external laryngeal nerve. In its course the superior laryngeal nerve is joined by twigs from the sympathetic and pharyngeal plexus.

The internal laryngeal nerve runs downwards and medially to reach the hyo-thyroid membrane and then enters into the larynx by piercing the hyo-thyroid membrane immediately above the superior laryngeal artery. In the larynx it divides into a superior and an inferior branch. The superior branch runs horizontally and supplies the mucous membrane of the pharynx, both the surfaces of the epiglottis, the vallecula and the mucous membrane of the larynx as far as the vocal folds. The other branch descends in the medial wall of the piriform fossa and gives branches to the aryepiglottic

fold and the mucous membrane covering the back of the arytaenoid cartilage and also supplies one or two twigs to the arytaenoid muscle.

The *external laryngeal nerve* descends downwards behind the superior thyroid artery and lies under cover of the sternothyroid muscle. It at first lies on the inferior constrictor muscle of the pharynx and then pierces it and finally winding round the inferior thyroid tubercle it enters the cricothyroid muscle and ends by supplying it.

Although it supplies mainly the cricothyroid muscle, it provides muscular branch to the inferior constrictor muscle of the pharynx and a communicating branch to the pharyngeal plexus and to the superior cardiac nerve.

Branches to the carotid body. They are minute filaments which arise from either the inferior ganglion directly or they pass through the pharyngeal branch and are distributed to the carotid body.

The recurrent laryngeal nerves. The recurrent laryngeal nerves are two in number, right and left, and each arises from the corresponding vagus nerve. The two nerves differ from each other, as to their place of origin, course and relation. The right recurrent laryngeal nerve arises in the neck from the right vagus while the left arises from the left vagus nerve in the thorax.

The right recurrent laryngeal nerve. It arises from the right vagus nerve in the neck and hooks round below the first part of the right subclavian artery and ascends upwards crossing posterior to the artery. It then passes obliquely upwards and medially behind the common carotid artery and reaches either in front of or behind the inferior thyroid artery or its branches or it may lie between its branches. Then it reaches the side of the trachea and ascends upwards in the groove between the trachea and the oesophagus being related to the medial side of the lobe of the thyroid gland and then pierces the inferior constrictor muscle of the pharynx and enters the larynx behind the articulation between the inferior cornu of the thyroid and the cricoid cartilage.

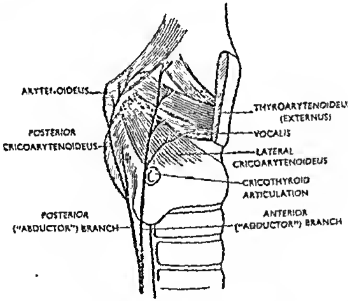


Fig. 838. Schema of the distribution of the recurrent laryngeal nerve. With kind permission from Prof. Hollinshead, Ph.D., Anatomy for the Surgeons, Vol. I, Paul B. Hoeber INC.

(1) *Cardiac branches* arise as the nerve winds round the subclavian artery and course downwards alongside the trachea to end into the deep part of the cardiac plexus.

(2) *Communicating branches* to the inferior cervical ganglion of the sympathetic arise from the nerve behind the subclavian artery.

(3) *Muscular branches* supply the trachea, oesophagus and the inferior constrictor muscle of the pharynx.

(4) *Terminal branches* supply all the muscles of the larynx (except the crico-thyroid) and communicate below the lamina of the thyroid cartilage with the branches of the internal laryngeal nerve and supply the mucous membranes of the larynx below the vocal fold.

The *left recurrent laryngeal nerve.* It arises from the left vagus nerve as it crosses the arch of the aorta and then hooks round below the arch of the aorta lateral to the ligamentum arteriosum. It ascends upwards in the groove between the trachea and the oesophagus to the neck where its course and relations are similar to that of the nerve of the right side. The branches of distribution are the same as those of the right nerve. The cardiac branches arise from the vagus nerve both in the upper and lower parts of the neck and are divided into superior and inferior branches.

The superior branches join with the cardiac branches of the sympathetic trunk and end in the deep part of the cardiac plexus.

The inferior branches from the right side pass in front of the innominate artery and end in the deep part of the cardiac plexus. Those from the left side cross in front of the arch of the aorta and end in the cardiac plexus.

Pulmonary branches. They form anterior and posterior branches which end in the corresponding pulmonary plexuses.

Oesophageal branches. They form oesophageal plexus both in front of and behind the oesophagus.

Gastric branches. The gastric branches supply the stomach and form anterior and posterior gastric plexuses. The antero-superior surface is supplied by the branches from the left vagus nerve while the postero-inferior surface is supplied by the branches from the right vagus nerve. The pyloric canal, the pyloric antrum and the first part of the duodenum are supplied by branches from the hepatic branches of the vagus nerve.

Coeliac branches. They are distributed to the coeliac ganglion and are derived from the right vagus nerve.

Hepatic branches. They arise from both the vagus nerves and join in the hepatic plexus through which they pass to the liver.

THE ACCESSORY NERVE

It is the eleventh cranial nerve and is entirely motor in function.

Origin. It arises by two roots, cranial and spinal.

Cranial root. It arises from the lower part of the nucleus ambiguus (deep origin) and emerges from the medulla below the vagus nerve (superficial origin). From its origin at the brain stem it passes laterally to the jugular foramen where it unites with its spinal root and is also connected with the superior ganglion of the vagus nerve by one or two filaments. Then it passes through the jugular foramen and after its exit from the same it is separated from the spinal root and is distributed to the inferior ganglion of the vagus nerve. It is through the pharyngeal, recurrent laryngeal and cardiac branches of the vagus nerve that the accessory nerve supplies its motor filaments to the muscles of the soft palate, intrinsic muscles of the larynx and the musculature of the heart.

Spinal root. It arises from an elongated nucleus situated at the anterior grey column of the spinal cord extending up to the level of the fifth cervical nerve. The rootlets of the nerve unite to form a trunk which ascends upwards through the foramen magnum behind the vertebral artery and reaches the jugular foramen where it is united with its cranial root, and passes through the intermediate compart-

ment of the jugular foramen and after its exit it leaves its cranial root and lies either superficial or deep to the internal jugular vein. In this situation it crosses the transverse process of the atlas, being itself crossed by the occipital artery. It then descends obliquely behind the styloid process, the stylohyoid and the posterior belly of the digastric muscles and accompanying the upper sternomastoid branch of the occipital artery it reaches the sternomastoid muscle and enters its deep surface. In its course through the muscle it is joined by a branch from the second cervical and provides muscular branch for the sternomastoid muscle. It emerges from the muscle from opposite the middle of its posterior border and descends obliquely through the posterior triangle and lies on the levator scapulae muscle. Here the nerve is superficial, being only covered by skin, superficial fascia and platysma and is joined by the communicating branches from the second and the third cervical nerves. Finally about 5 cm. above the clavicle it disappears into the deep surface of the trapezius muscle under cover of its anterior border. On the deep surface of the trapezius it forms a plexus with the branches from the third and the fourth cervical nerves from which the muscle is enervated.

THE HYPOGLOSSAL NERVE

It is the twelfth cranial nerve, entirely motor (somatic) in function and supplies all the muscles of the tongue except the palatoglossus.

Deep origin. It arises from the hypoglossal nucleus situated in the hypoglossal triangle at the lower part of the floor of the fourth ventricle.

Superficial origin. The rootlets of the nerve emerge from the brain stem through the antero-lateral sulcus between the pyramid and olive of the medulla oblongata.

Course and relation. The fibres of the nerve are arranged to form two roots which pass laterally behind the vertebral artery and pierce the dura mater separately and then pass through the hypoglossal (anterior condyloid) canal at the lower part of which the two roots unite to form a single nerve trunk. Here the nerve lies deep to internal carotid artery, internal jugular vein, vagus, accessory, and glossopharyngeal nerves. The nerve next turns laterally behind the internal carotid artery, vagus and glossopharyngeal nerves to reach the interval between the internal jugular vein and the internal carotid artery. Then the nerve descends downwards as far as the angle of the mandible where it turns medially hooking the lower sternomastoid branch of the occipital artery.

Then it turns further medially crossing the occipital, external carotid and the loop of the lingual arteries. Then it ascends upwards beneath the posterior belly of digastric, stylohyoid and the posterior part of the mylohyoid to gain the superficial surface of the hypoglossus muscle which separates it from the second part of the lingual artery. Here the lingual nerve and the submandibular duct are placed above the hypoglossal nerve. Finally, it pierces through the fibres of the genioglossus to reach the tip of the tongue where it ends by dividing into muscular branches.

Branches:

(1) *Meningeal branch.* It arises from the hypoglossal nerve as it traverses through the hypoglossal canal and ascends to enter the cranial cavity where it supplies the dura mater of the posterior cranial fossa.

(2) *Descending branch.* It descends through the carotid sheath carrying fibres from C1 and after supplying a branch to the superior belly of the omohyoid it unites with the descendant cervicalis from the second and the third cervical nerves to form the ansa cervicalis (hypoglossi). From the ansa branches are given to sternohyoid, sternothyroid, and the inferior belly of the omohyoid.

(3) *Thyrohyoid branch.* This is an independent branch which carries fibres from C1 for the same muscle.

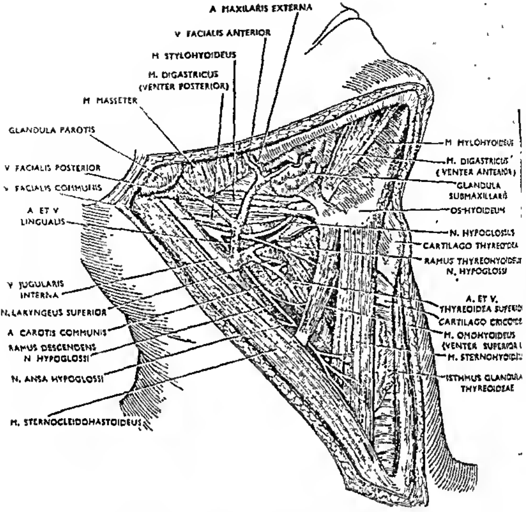


Fig 839. The dissection of the anterior triangle of the neck. Right side. Note the position of the hypoglossal nerve With kind permission from Callander: Surgical Anatomy, 2nd Ed, 1939; W. B Saunder's Company, Philadelphia and London.

(4) *Muscular.* These are branches given to supply styloglossus, hyoglossus, genioglossus, geniohyoid, chondroglossus and terminal muscular branches to all the intrinsic muscles of the tongue.

(5) *Communicating branches* are given to lingual, first and second cervical, sympathetic and vagus nerves.

THE SPINAL NERVES

The spinal nerves are attached to the medulla spinalis (spinal cord) in series from above downwards on its either side and consist of thirty-one pairs of nerves which are grouped as cervical 8, thoracic 12, lumbar 5, sacral 5 and coccygeal 1.

Position in relation to the vertebrae. The first cervical nerve lies on the posterior arch of the atlas below the occipital bone and is known as the *suboccipital nerve*. The eighth cervical nerve lies between the seventh cervical and the first thoracic vertebrae and the other cervical nerves are named numerically equivalent to the number of the vertebra that lies below it. All other spinal nerves are named numerically after the numerical value of the vertebra that lies above it.

Formation. Each spinal nerve consists of two roots, ventral and dorsal, by means of which it is attached to the medulla spinalis, which unite together at the intervertebral foramen to form the nerve trunk.

ANTERIOR ROOT. *Attachment.* It is attached to the anterior surface of the medulla spinalis by several irregularly scattered nerve fibres. It is more slender than the posterior root.

Functional components and origin. Functionally, the anterior root is motor in function and consists of somatic and visceral autonomic efferent fibers. The somatic efferent fibres arise from the multipolar cells of the anterior horn of the medulla spinalis whereas the visceral efferent fibres have their cells of origin in the lateral horn. Developmentally the anterior root fibres are the derivative of the basal lamina of the neural tube.

POSTERIOR ROOT. *Attachment and size.* The posterior root is attached to the posterolateral sulcus of the medulla spinalis by several nerve fibres and the attachment is more precise and orderly than the anterior root. It is larger in comparison to the anterior root and is characterised by the presence of a ganglion.

Functional components and origin. Functionally, the posterior root is sensory and carries both somatic and visceral afferent fibres. The fibres of the posterior root form the central processes of the cells of the posterior root ganglion which terminate by synapse around the cells of the posterior horn of the medulla spinalis. Developmentally the posterior root is the derivative of the neural crest.

The posterior root ganglion. Each ganglion is roughly oval in form, and with the exception of the coccygeal nerve all the ganglia lie outside the dura mater although they receive investments from the latter. The cells of the ganglia are of unipolar type whose central processes are attached to the medulla spinalis whereas their peripheral processes unite with the anterior root.

Connections. Each spinal nerve receives a branch (grey ramus communicans) from the corresponding sympathetic ganglion, and all the thoracic and the first and the second lumbar nerves provide, each, a branch (white ramus communicans) to the corresponding sympathetic ganglion. The second, third and the fourth sacral nerves provide autonomic branches which instead of joining with the corresponding sympathetic ganglion join with pelvic plexuses of autonomic system. These autonomic branches from the second, third and the fourth sacral nerves carry parasympathetic fibres and are known as the *pelvic spalnchnic nerves*.

Divisions. Each spinal nerve immediately after its exit from the intervertebral foramen provides a meningeal branch which re-enters the vertebral canal and is distributed to the spinal meninges and then at once divides into ventral and dorsal rami or divisions.

THE DORSAL DIVISIONS OR RAMI OF THE SPINAL NERVES

The dorsal rami (posterior primary rami) of the spinal nerves are usually smaller than the ventral rami except in case of the 1st cervical nerve where the dorsal ramus is larger than the ventral one. Each of the dorsal rami divides into medial and lateral branches except the first and the last spinal nerves and the fourth and the fifth sacral nerves. They supply both muscles and the skin.

DORSAL RAMI OF THE CERVICAL SPINAL NERVES

The dorsal ramus of the first cervical nerve. It differs from the other dorsal branches in many respects. (1) The dorsal branch of the first cervical nerve is larger than its ventral branch. (2) It does not split into medial and lateral branches. (3) It has no direct cutaneous branch.

It lies in the floor of the suboccipital triangle and lies below and behind the third part of the vertebral artery. It provides *muscular branches* which supply the muscle of the suboccipital triangle namely, rectus capitis posterior major et minor, obliquus capitis superior et inferior and the semispinalis capitis. It also supplies a communicating branch which descends downwards to join with the second cervical nerve (greater occipital).

The dorsal branch of the second cervical nerve. It is also larger than its ventral branch. It runs backwards between the atlas and the axis and lies between the obliquus capitis inferior and the semispinalis cervicis under cover of the semispinalis capitis and then divides into muscular and communicating branches. The muscular branches supply the semispinalis capitis et cervicis, the obliquus capitis inferior and the multifidus. Its communicating branch communicates with the first cervical, great auricular, lesser occipital, posterior auricular and the third occipital nerves. After providing branches it is continued as the **greater occipital** nerve which pierces through the semispinalis capitis and the trapezius and then accompanies the occipital artery and finally becomes cutaneous which supplies the scalp in the posterior region and ascends upwards as far as the vertex of the skull.

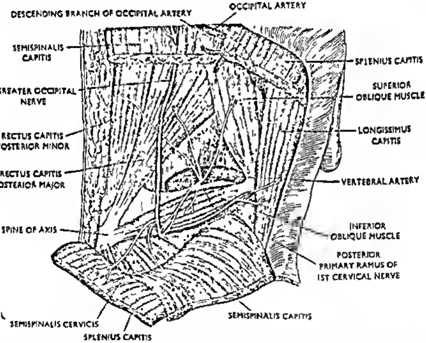


Fig. 810. The muscles of the right suboccipital triangle with the structures contained within it. The veins has been removed. Note the position of the sub-occipital nerve.

The posterior or dorsal branch of the third cervical nerve. It divides into a medial, cutaneous branch, and a lateral, muscular branch. Its medial cutaneous branch is known as the **third occipital nerve** which runs backwards and medially to supply the skin of the neck and scalp on the dorsal region. Its muscular branches supply the adjacent muscles. It communicates with the greater occipital nerve.

The dorsal branches of the remaining cervical nerves. The dorsal branches of the fourth, fifth, sixth, seventh and the eighth cervical nerves divide into medial cutaneous and lateral muscular branches under cover of the semispinalis capitis. The cutaneous branches run backwards and end by supplying the skin of the dorsal region of the neck adjoining the median plane. The cutaneous branches of the lower two nerves may fail to reach the skin in some cases. The lateral muscular branches supply the iliocostalis cervicis, longissimus cervicis et capitis.

THE DORSAL RAMI OR BRANCHES OF THORACIC NERVES

The dorsal rami of the thoracic spinal nerves divide into medial and lateral branches. The medial branches are cutaneous in the upper six or seven thoracic nerves while in the lower five or six thoracic nerves the reverse is the case in which the lateral branches are cutaneous while their medial branches are muscular. The medial branches of the upper thoracic nerves pierce the rhomboideus and trapezius and deep fascia and then they become cutaneous and supply the skin adjoining the spines. The corresponding lateral branches end by supplying the deep muscles of the back. The lateral branches of the lower series are cutaneous and they gradually become longer and more oblique from above downwards. They supply the longissimus thoracis, iliocostalis cervicis and the levatores costarum, pierce these muscles and then become cutaneous. The lower nerves of this series also pierce the serratus posterior inferior before becoming cutaneous. The lateral branch of the twelfth thoracic nerve crosses the iliac crest and then ends by supplying the skin in the anterior part of the buttock.

THE DORSAL RAMI OR BRANCHES OF THE LUMBAR NERVES

The dorsal rami of the lumbar nerves also divide into lateral and medial branches.

The medial branches are short and they end by supplying the multifidus muscle.

The lateral branches of the upper three lumbar nerves are cutaneous and they supply the errector spinae (saerospinalis) and running laterally and downwards through the fibres of the same muscle they become superficial by piercing the lumbar fascia above the iliac crest a short distance in front of the posterior superior iliac spine. They descend on to the gluteal region and supply a strip of skin extending from above the iliac crest to the distal and posterior part of the greater trochanter of femur. The dorsal branches of the lower two lumbar nerves only supply the deep muscles of the back.

THE DORSAL RAMI OF THE SACRAL AND COCCYGEAL NERVES

The dorsal rami of the first three sacral nerves divide into lateral cutaneous and medial muscular branches. The medial muscular branches end by supplying the multifidus muscle. *The lateral cutaneous branches unite with one another* and the first also joins with last lumbar nerve, and the third sacral with the fourth to form a loop. Branches from this loop pierce the sacrotuberous ligament and then form another loop which pierce the gluteus maximus muscle and supply the skin in the sacral region and the adjoining gluteal region.

The dorsal rami of the fourth and the fifth sacral nerves do not divide into branches but they are united together to form a loop which joins with the coccygeal nerve to form a single trunk which pierces the sacrotuberous ligament and then end by supplying the skin and fascia in the region of the coccyx.

THE CERVICAL PLEXUS AND ITS BRANCHES

The anterior primary rami of the first four cervical nerves are connected to each other to form loops which constitute the formation of the *cervical plexus*. The plexus is situated in front of the upper four cervical vertebrae, scalenus medius, levator scapulae and the rectus capitis lateralis muscle and is overlapped by the sternocleidomastoid muscle and the internal jugular vein. Each nerve at its emergence from the intervertebral foramen is joined by the grey rami communicans from the superior cervical sympathetic ganglion.

From the loops of the plexus the branches of distribution arise as (1) cutaneous branches to the head, neck and shoulder; (2) muscular branches to muscles of the neck and to the diaphragm and (3) communicating branches to vagus, accessory hypoglossal and sympathetic nerves.

Cutaneous branches—

A. *Ascending branches* (C.2.3)
(1) Lesser occipital nerve
(2) Great auricular nerve
(3) Anterior cutaneous nerve

B. *Descending branches* (C.3.4)
(1) Supraclavicular nerves

Muscular branches—

A *Lateral branches*
(1) Muscular branches to Sternocleidomastoid (C.2)
(2) Trapezius (C.3,4)
(3) Levator scapulae (C.3,4)
(4) Scaleni (medius and posterior) (C.3,4.)

B. *Medial branches*
(1) Muscular to prevertebral muscles (C.1,2,3,4).
(2) Infrahyoid muscles (C.1,2,3) (ansa cervicalis)
(3) Diaphragm (C.3,4,5) (Phrenic nerve)

Communicating branches—

To Accessory nerve (C.2,3,4)
To Vagus (C.1,2)
To Hypoglossal nerve (C.1,2)
To Ansa cervicalis (hypoglossi) (C.2,3)
To Sympathetic (C.1,2,3,4)

(1) **The Lesser occipital nerve.** It arises from the third or the second cervical nerve and hooking round the accessory nerve ascends upwards along the posterior border of the sternocleidomastoid muscle and divides into branches which supply the skin covering the head behind the auricle. It communicates with the great auricular and greater occipital nerves and the posterior auricular branch of the facial nerve.

(2) **The great auricular nerve.** It arises from the second and third cervical nerves and winds round the posterior border of the sternocleidomastoid under the deep fascia and accompanying the external jugular vein reaches the parotid gland where it divides into three branches, facial, auricular and mastoid. The *facial branch* supplies the skin covering the lower part of the parotid gland and communicates in the substance of the gland with the facial nerve. The *auricular branch* supplies the skin covering the lobule and the lower part of the ear. The *mastoid branch* supplies the skin covering the mastoid process of the temporal bone. The last two branches, communicate with the lesser occipital, auricular branch of the vagus nerve and the posterior auricular branch of the facial nerve.

(3) **Anterior cutaneous nerve of the neck.** It arises from the second and the third cervical nerves and crosses obliquely the superficial surface of the streno-cleidomastoid muscle opposite the middle of its extent and then piercing the deep fascia divides into ascending and descending branches which supply the skin of the anterolateral region of the neck. The ascending branches communicate with the cervical branch of the facial nerve.

Supraclavicular nerves. They arise by a common trunk from the third and the fourth cervical nerves which emerge from under cover of the posterior border.

of the sternocleidomastoid muscle and then descend downwards beneath the platysma and the deep fascia.

A little above the clavicle it divides into medial, intermediate and lateral branches which pierce the deep fascia and the platysma. The *medial branch* supplies the skin as far as the median plane. It also provides one or two filaments to the sternoclavicular joint. The *intermediate branch* crosses over the clavicle and supplies the skin covering the pectoralis major and the deltoid muscles as low as the level of the second rib. It communicates with the cutaneous branches of the upper intercostal nerves. The *lateral supraclavicular nerve* passes obliquely across the outer surface of the trapezius and the acromion and supplies the skin covering the upper and posterior part of the shoulder.

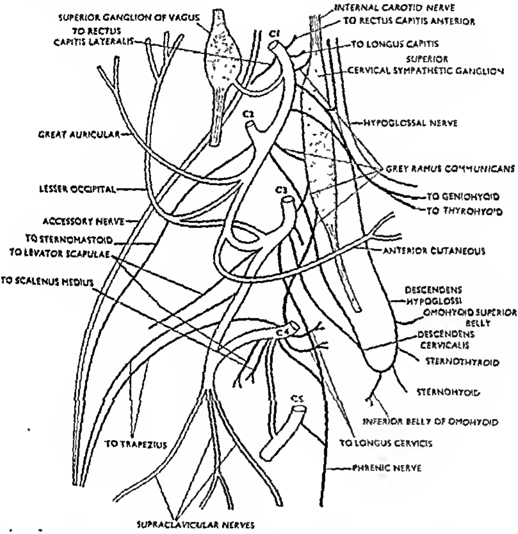


Fig. 841. A schematic drawing of the cervical plexus and its connections and branches.

Lateral muscular branches. These branches supply the sternocleidomastoid trapezius, levator scapulae and the scalenus medius et posterior.

The branch to the sternocleidomastoid is derived from the second cervical nerve which enters into its deep surface and communicates with the accessory nerve while the trapezius and the levator scapulae are supplied by branches from the third and the fourth cervical nerves. The branches to the trapezius muscle obliquely cross the posterior triangle in parallel with the accessory nerve and then enter into its deep surface. They communicate with the accessory nerve both in the posterior

triangle as well in the back on the deep surface of the muscle. The branches fr third and the fourth cervical nerves supplying the levator scapulae enter into lateral surface as two branches in the posterior triangle. The scalenus medius posterior are also supplied by branches from the third and the fourth cervical nerve

Medial muscular branches. The longus capitis and the rectus capitis anterior and lateralis, muscles of the prevertebral group, are supplied by small branches coming from the loop between first and the second cervical nerves. The longus capitis also receives branches from the third and the fourth nerves as well. The longus cervicis receives branches from the second, third and the fourth cervical nerves. The scalenus medius and posterior receive branches from the third and the fourth cervical nerves. The phrenic nerve arises from the third, fourth and the fifth cervical nerves and is distributed mainly in the diaphragm and has been described below.

Communicating branches. They communicate with the vagus, accessory and hypoglossal nerves and with the superior cervical sympathetic ganglion.

The *inferior ganglion of the vagus* receives a communicating branch from the loop between the first and the second cervical nerves.

The *accessory nerve* receives a communicating branch from the second cervical nerve under cover of the sternocleidomastoid muscle; in the posterior triangle it receives communicating branches from the third and the fourth cervical nerve under cover of the trapezius it also receives communicating branches from the third and the fourth cervical nerves which carry proprioseptive sensations from the trapezius.

The *hypoglossal nerve* receives a communicating branch from the loop between the first and the second cervical nerves at its exit from the hypoglossal canal and carries fibres mostly from the first cervical nerve. Some of these fibres enter the cranial cavity along with the hypoglossal nerve and leaves it as its *meningeal branch* which supplies the dura mater in the posterior cranial fossa. Other components of the cervical nerve leave the hypoglossal nerve as the muscular branches to the geniohyoid and thyrohyoid and as the *upper root of the ansa cervicalis* (*ramus descendens cervicalis*) in the carotid triangle. The upper root of the ansa cervicalis descends in front of the carotid sheath, supplies the superior belly of the omohyoid and joins with the branches from the second and the third cervical nerves in front of the carotid sheath, which form the lower or inferior root of the ansa cervicalis, to form the *ansa cervicalis*. Branches from the ansa cervicalis supply the sternohyoid, sternothyroid and the inferior belly of the omohyoid muscle.

Each of the upper four cervical nerves receives a grey ramus communicans from the *superior cervical sympathetic ganglion*.

The phrenic nerve. It is a mixed nerve and carries both motor and sensory fibres. It arises in the neck from the anterior primary rami of the third, the fourth and the fifth cervical nerves but majority of its fibres are derived from the fourth cervical nerve.

After being formed at the lateral border of the scalenus anterior muscle, the phrenic nerve descends in front of that muscle to the root of the neck; then it enters the thorax by crossing the internal thoracic artery from lateral to medial side and then descends vertically downwards in front of the root of the lungs to reach the diaphragm muscle where it ends chiefly by supplying this muscle although some of its filaments are continued downwards in the abdomen to end into the coeliac plexus. According to its situation it may be divided into cervical and thoracic portions.

Relation (*Cervical portion*). In the neck it descends obliquely downwards in front of the scalenus anterior muscle and is covered by the sternomastoid and the inferior belly of the omohyoid muscle. In its course downwards it is crossed transversely by the suprascapular and transverse cervical arteries. At the root of the neck and on the left side it passes in front of the first part of the subclavian artery

and intervenes between it and the subclavian vein and is crossed by the thoracic duct; on the right side it is separated from the second portion of the subclavian artery by the scalenus anterior muscle.

Thoracic portion. In the thorax the phrenic nerve is accompanied by the pericardiaco-phrenic vessels and the two nerves differ from each other in their course and relation. The left phrenic nerve is usually more oblique and larger than the right owing to the heart being placed more on the left side than the right side and the diaphragm being more on a lower level. Besides this they also differ in their relations.

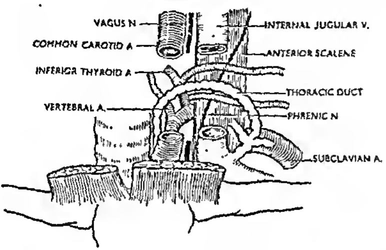


Fig. 842. Some relations in front of the scalenus anterior muscle on the left side. Note the position of the phrenic nerve. With kind permission from W. H. Hollinshead, Ph D, Anatomy for the Surgeons; Paul B. Hoeber INC

Left phrenic nerve. The *left phrenic nerve* descends downwards in between the left subclavian and the left common carotid arteries and crosses superficial to the vagus nerve and the arch of the aorta. In this situation it is crossed deeply by the left superior intercostal vein. Then the nerve lies in intimate contact with the pericardium which separates it from the left ventricle of the heart.

Right phrenic nerve. The right phrenic nerve is more deeply seated and is placed on the right side of the right innominate vein and the superior vena cava; it then descends on the right side of the pericardium which separates it from the right atrium of the heart.

Each phrenic nerve provides some pericardial and pleural branches in spite of its principal supply to the diaphragm muscle. In the neck it is joined by a branch from the sympathetic.

N.B. This is to note that the phrenic nerve is the *only motor* nerve supplying the diaphragm while the supply it derives from the lower six or seven intercostal nerves are sensory in function for the peripheral portion of the diaphragm. The phrenic also supplies sensory filaments to the central portion of the diaphragm. A few branches from the right phrenic nerve descend in the abdomen and join with the phrenic branches of the coeliac plexus to form the phrenic ganglion from which branches are given off to the right suprarenal gland, coronary and falciform ligaments and the right part of the inferior vena cava. Similar branches from the left phrenic nerve join with the phrenic branches of coeliac plexus without any gangliform enlargement and supply the left spurarenal gland.

THE BRACHIAL PLEXUS OF NERVES

Formation. The brachial plexus is formed by the union of the anterior primary rami of the lower four cervical nerves and the greater part of the anterior primary ramus of the first thoracic nerve. The most usual and almost constant mode of union between the nerve roots and their subsequent arrangements are as follows:

Four stages may always be identified—

(1) The undivided anterior rami of the nerves.
(2) The formations of the three trunks.
(3) The separation of each trunk into anterior and posterior divisions.
(4) The union of the divisions to form the cords from which the nerv distribution originate.

Erbspoint

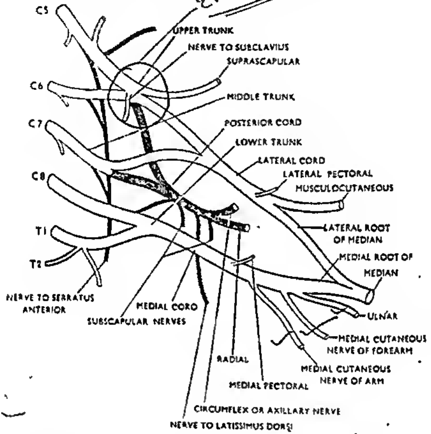
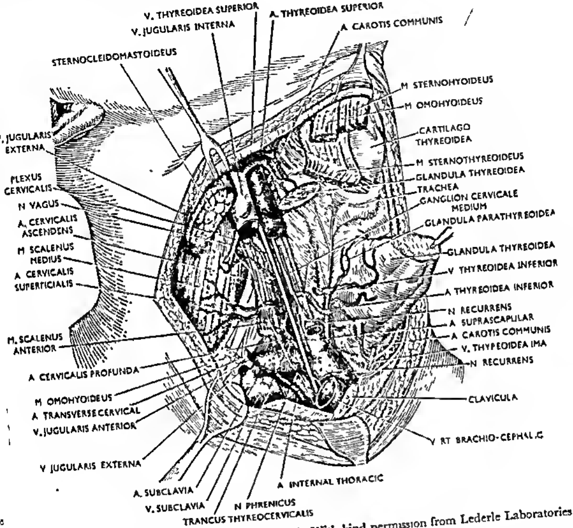


Fig. 843 A schematic drawing of the brachial plexus of nerves with its branches

The undivided anterior rami of the nerves and the formations of the three trunks. The fifth cervical nerve, supplemented by a branch from the fourth, unites with the sixth cervical nerve at the lateral border of the scalenus anterior muscle to form a nerve trunk, the *upper trunk of the plexus.* The seventh cervical nerve runs independently behind the scalenus anterior to form the *middle trunk of the plexus.* The first thoracic nerve, supplemented by a twig from the second thoracic nerve, unites with the eight cervical to form the *lower trunk of the plexus* which is placed beneath the lower part of the scalenus anterior muscle.

Separation of each trunk into an anterior and posterior divisions. The three trunks thus formed, upper, middle and lower, descend downwards and laterally and as they pass beneath the clavicle each trunk splits up into anterior and posterior branches. The anterior branch of the upper trunk unites with the anterior branch of the middle trunk to form the *lateral cord of the brachial plexus.* The anterior division of the lower trunk runs alone to form the *medial cord of the plexus.* The posterior divisions of all the three trunks unite together to form the *posterior cord of the brachial plexus.* Thus we see that the brachial plexus consists of nerve roots, nerve trunks and the cords. The nerve roots of the fifth and the sixth cervical nerves close to

ir exit from the intervertebral foramen receive grey rami communicans from the ddle cervical sympathetic ganglion. The seventh and eighth nerve roots receive ilar rami from the inferior cervical sympathetic ganglion. The first thoracic ceives a grey ramus from the first thoracic ganglion and supplies a white ramus the first thoracic sympathetic ganglion.



g. 844. The great vessels and nerves of the neck. With kind permission from Lederle Laboratories Ltd. Drawn by Mr. Paul Peck.

Course. The brachial plexus is situated in the lower part of the neck in the ingle between the clavicle and the posterior border of the sternocleidomastoid muscle where the roots of the nerve unite to form the nerve trunks which descend downwards and laterally and then the trunks divide into cords which pass beneath the clavicle to the axilla.

Relations in the neck. In the neck the brachial plexus is situated in the lower part of the posterior triangle and occupies the angular interval between the clavicle and the posterior border of the sternocleidomastoid muscle. In this situation it is more or less superficial being covered only by the skin, superficial fascia, platysma and the deep fascia and is crossed by the supraclavicular nerves from the cervical plexus, nerve to the subclavius, the inferior belly of the omohyoid muscle,—the external jugular vein, and the transverse cervical artery. The nerve trunk formed by the nerve roots emerge from the neck between the scalenus anterior and the

scalenus medius muscles. In this situation the upper and the middle trunks lie above the third part of the subclavian artery while the lower trunk lies behind the artery. As it passes behind the clavicle and the subclavius muscle it is crossed by the suprascapular vessels and lies upon the first digitation of the serratus anterior and the subscapularis muscle.

In the axilla the plexus at first lies upon the first and part of the second digitations of the serratus anterior, then on the subscapularis and the teres major muscles. The lateral and the posterior cords of the plexus lie on the lateral side of the first part of the axillary artery while the medial cord lies posterior to it. Opposite the second part of the axillary artery it is covered by the pectoralis minor muscle and the three cords surround the three sides of the artery according to their name. The medial cord intervenes between the axillary artery and the vein. In the lower part of the axilla the branches of the plexus bear the following relations with the third part of the axillary artery. The musculo-cutaneous nerve and the lateral root of the median lie on the lateral side of the artery. The radial and the axillary (circumflex) nerves lie posteriorly. Medial to the artery are the ulnar nerve and the medial cutaneous nerve of the forearm which intervene between it and the axillary vein. Of the two nerves the ulnar nerve is posterior and the medial cutaneous nerve of the forearm is anterior. The medial cutaneous nerve of the arm lies on the medial aspect of the axillary vein which separates it from the ulnar and the medial cutaneous nerves of the forearm.

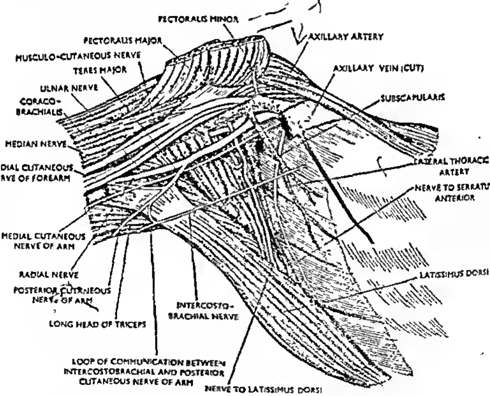


Fig. 845. The brachial plexus of the nerves with the axillary vessels. From the dissection hall N. R. Sircar Medical College, Calcutta; with kind permission from the Prof. of Anatomy

The trunk of the median nerve is formed either in front of or on the lateral side of the third part of the axillary artery.

The branches of the brachial plexus are grouped into supraclavicular and infraclavicular branches according to their origin above and below the clavicle.

Supraclavicular branches—

(1) Arising from the nerve roots—

(a) *Anterior branches*

(i) Nerves to scalenus anterior and longus cervicis.

(ii) Communicating nerve to join the phrenic nerve.

(b) *Posterior branches—*

(i) Nerve to scalenus medius et posterior.

(ii) Dorsal scapular nerve (Nerve to the rhomboids.)

(iii) Long thoracic nerve (Nerve to the serratus anterior).

(2) Arising from the nerve trunk—

(i) Nerve to the subclavius.

(ii) Suprascapular nerve.

From the upper trunk of the brachial plexus.

. Infraclavicular branches—

From the lateral cord—

1. Lateral pectoral.
2. Lateral root of median.
3. Musculocutaneous.

From the medial cord—

1. Medial pectoral.
2. Medial root of the median.
3. Ulnar.
4. Medial cutaneous nerve of the forearm.
   Medial cutaneous nerve of the arm.

From the posterior cord—

1. Radial.
2. Axillary (Circumflex).
3. Upper and lower subscapular nerves.
4. Thoracodorsal (nerve to the latissimus dorsi).

Injury to the brachial plexus. The possible causes of injury to the brachial plexus are falls on the side of the neck, stretching of the upper limb, wound in the axilla or neck, and the stretching of the neck during forcep delivery in child-birth. When the brachial plexus is stretched either from fall or from forcep delivery during child-birth it is the Erb's point where the nerve trunk is stretched or severed. The point of union between the fifth and sixth cervical nerves constitutes the Erb's point where six nerves meet, namely, fifth and sixth cervical nerves unite to form the upper trunk which divides into anterior and posterior branches. So four nerves meet here, and the suprascapular nerve arises from the upper part of the trunk and the nerve to the subclavius from the lower part. Besides the Erb's point other nerves may also be involved and the signs and symptoms arising out of injury to the brachial plexus may be conveniently divided into (a) upper arm type or Erb-Duchanne type, (b) lower arm type or Klumpke's type and (c) the total arm type.

Erb-Duchanne type or upper arm type of paralysis. In case of injury to the Erb's point muscles enervated by the fifth and sixth nerves through its constituents will be affected in general but the following muscles suffer most:

(1) Deltoid.
(2) Supraspinatus.
(3) Infraspinatus.
(4) Biceps brachii.
(5) Brachialis.
(6) Coracobrachialis.
(7) Brachioradialis.
(8) Supinator.

Deformity—

(1) Abduction of the shoulder joint is impossible due to paralysis of deltoid ..d supraspinatus and consequently the arm remains adducted.

(2) Flexion of the elbow is impossible due to paralysis of the biceps and brachialis and the forearm remains extended,

(3) Forearm is pronated due to paralysis of both the supinators of the forearm (Biceps and supinator).

(4) Hand is flexed at the wrist and at the digits due to partial involvement of the extensors.

The actual deformity is that the hand hangs by the side with arm medially rotated, with the forearm completely pronated and the hand and fingers, partially flexed ("Porter Man's Tip" hand). Police man tip hand.

Klumpke's type or lower arm type of paralysis. In this type of paralysis usually the first thoracic nerve or the lowest trunk of the brachial plexus is involved during sudden raising of the point of shoulder, and consequent upon the injury of the first thoracic nerve the white ramus communicans to the cervical sympathetics will also be involved. The first thoracic nerve supplies the intrinsic muscles of the hand and through the white rami communicans it supplies the orbitalis muscle, the plain muscle over the levator palpebrae superioris and the sweat glands of the face and the dilator muscle of the pupil.

Deformity—

(1) Flattening of the thenar and hypothenar eminences due to paralysis and wasting of the thenar and hypothenar muscles.

(2) Proximal phalanges of the medial four fingers are hyper-extended and distal phalanges will be partially flexed due to paralysis of the lumbricales and the interossei.

(3) Anaesthesia of the skin on the medial side of the arm, forearm and the hand.

(4) Sympathetic paralysis will lead to ptosis, enophthalmos, pin-point pupil and absence of sweating on the same side of the face (Horner's Syndrome).

Total arm type of paralysis. In this all the nerves of the plexus are involved but usually the suprascapular, the long thoracic nerve (nerve to the serratus anterior) and the dorsal scapular nerve (nerve to the rhomboids) escape and a test of the muscles supplied by these nerves will lead to diagnosis.

The radial nerve. The radial nerve supplies all the extensor muscles of the forearm, the triceps brachii, the elbow and the wrist joints and the skin over the back of the forearm, back of the lower part of the arm and the lateral side of the back of the hand.

It is the larger terminal branch of the posterior cord of the brachial plexus and its fibres are derived from the fifth, sixth, seventh and eighth cervical and the first thoracic nerves (Anterior primary rami). From its origin in the axilla it passes through the arm and forearm and finally is distributed to the dorsum of the hand and the digits. Its course and relations may conveniently divided into three parts —radial nerve in the axilla and arm, in the forearm and in the dorsum of the hand.

Radial nerve in the axilla and in the arm. It begins in the axilla as the larger terminal branch of the posterior cord of the brachial plexus and lies in front of the subscapularis muscle on the posterior wall of the axilla. It then descends downwards and laterally in front of the subscapularis muscle on the lateral side of the axillary (circumflex) nerve and behind the third part of the axillary artery. It then reaches the lower border of the subscapularis muscle and enters the arm by crossing the intermuscular gap between the subscapularis and the teres major et latissimus dorsi. In this situation the subscapular vessels intervene between it and the axillary (circumflex) nerve (the subscapular vessels may descend in front of it). In the arm it lies behind the brachial artery and in front of the teres major et latissimus dorsi and then accompanying the arteria profunda brachii it inclines backwards and runs in between the long and the medial heads of the triceps and enters into the spiral groove where it is covered by the lateral head of the triceps. It then accompanies the anterior descending branch of the arteria profunda brachii and running forwards

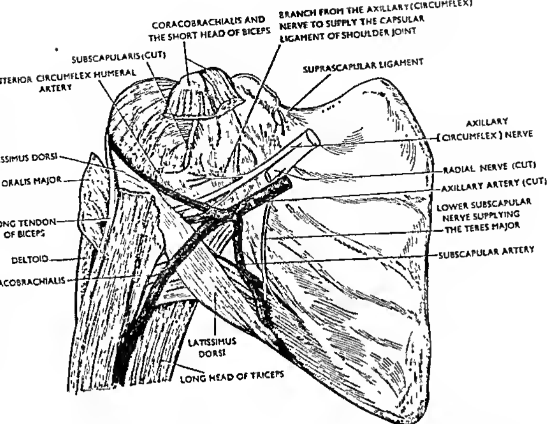


Fig. 846. The ventral aspect of the scapulo-humeral region with the removal of the subscapularis and a part of the coracobrachialis and the short head of biceps brachii. From the dissection hall, N. R. Sircar Medical College, Calcutta; with kind permission from the Prof of Anatomy.

it pierces the lateral intermuscular septum to enter into the anterior compartment of the arm. It then descends vertically downwards in front of the lateral intermuscular septum and lies in an intermuscular furrow bounded medially by the brachialis and laterally by the brachioradialis above and the extensor carpi radialis longus below. Finally it reaches the front of the lateral epicondyle where it gives out its posterior interosseous branch and then is continued into the forearm. A little above the elbow joint it gives out its articular branch to the same joint.

Branches in the axilla. In the axilla it gives out the *posterior cutaneous nerve of the arm* which supplies the skin on the back of the arm as far as the olecranon.

Branches in the arm.

(*a*) *Muscular branches.* (i) Medial muscular branches arise from it when it lies he medial side of the arm and supply the long and medial heads of the triceps.

(ii) *Posterior muscular branches* arise from it in the spiral groove and supply the ral and medial heads of the triceps and the anconeus. The nerve to the anconeus ompanies one of the branches of the arteria profunda brachii and by passing ough the medial head of the triceps it ends in the anconeus muscle.

(iii) *Lateral muscular branches* arise from it when it lies in the intermuscular fur- w in the anterior compartment of the arm and supply the brachioradialis, extensor rpi radialis longus and the lateral half of the brachialis.

(*b*) *Cutaneous branches.* They arise by a common trunk while the nerve lies in e spiral groove and after piercing the lateral head of the triceps and the deep

fascia divides into lower lateral cutaneous nerve of the arm and the posterior cutaneous nerve of the forearm.

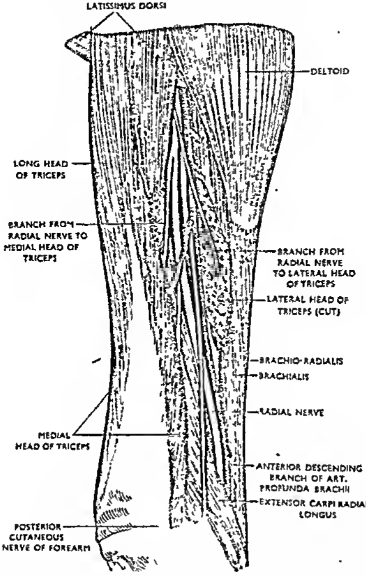


Fig. 847. The postero-lateral aspect of the right arm. A part of the lateral head of triceps has been removed to expose the radial nerve with its accompanying vessels. From the dissection hall, N. R. Sircar Medical College, Calcutta; with kind permission from the Prof. of Anatomy.

(i) Lower lateral cutaneous nerve of the arm. It supplies the skin on the lower and lateral part of the arm.

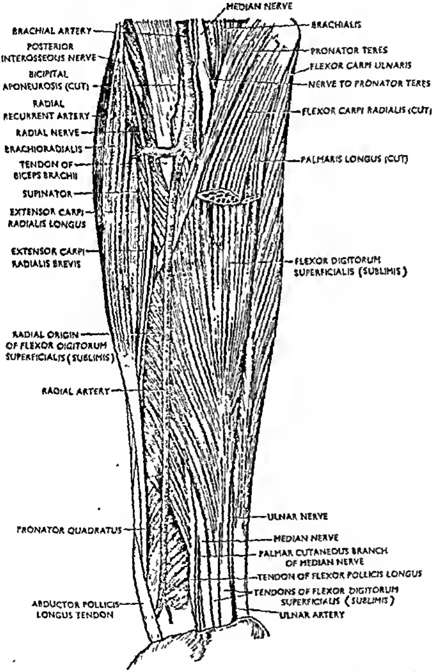
(ii) Posterior cutaneous nerve of the forearm. It supplies the skin on the back of the forearm as far as the back of the wrist joint and communicates with the dorsal branch of the lateral cutaneous nerve of the forearm.

(c) *Articular branch.* It supplies the elbow joint.

(d) *Posterior interosseous.* (see page 1096).

Radial nerve in the forearm. After giving the posterior interosseous branch in front of the lateral epicondyle, the radial nerve enters the forearm under

cover of the brachioradialis and lies at first in the lateral part of the cubital fossa in the intermuscular space between the brachioradialis in front and the supinator behind. In the cubital fossa it is separated from the radial artery by a considerable distance. It then lies successively upon the supinator, insertion of the pronator teres, radial origin of the flexor digitorum superficialis (sublimis) and flexor pollicis longus muscles and under cover of the brachioradialis. From opposite the level of insertion of the pronator teres it descends on the lateral side of the radial artery up to a point about 3 inches above the wrist joint from where it quits the artery and passes laterally beneath the tendon of the brachioradialis and finally after piercing the deep fascia it reaches the lateral part of the back of the hand.



. 848. The front of the right forearm with the removal of palmaris longus and flexor carpi adialis. Note the position of the median nerve. From the dissection hall, N. R. Sircar Medical College, Calcutta; with kind permission from the Prof. of Anatomy.

Branches. No branches are given out by the radial nerve in the forearm.

Radial nerve on the dorsum of the hand. On the dorsum of the hand the radial nerve divides into five or sometimes four branches. The first supplies the skin on the radial side and the ball of the thumb and communicates with the lateral cutaneous nerve of the forearm. The second supplies the medial side of the thumb, the third supplying the radial side of the index finger. The fourth divides into two collateral branches which supply the contiguous sides of the index and the middle fingers, the fifth, when it exists, communicates with the dorsal branch of the ulnar nerve and then supplies the contiguous sides of the middle and the ring fingers.

On the dorsum of the hand the radial nerve communicates with the lateral cutaneous nerve of the forearm and also with the posterior cutaneous nerve of the forearm

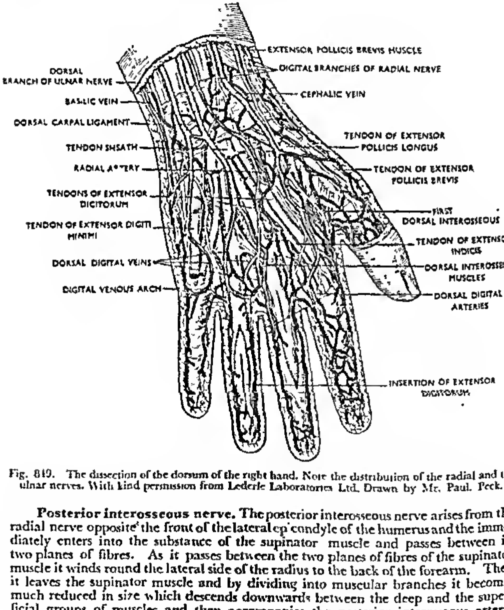
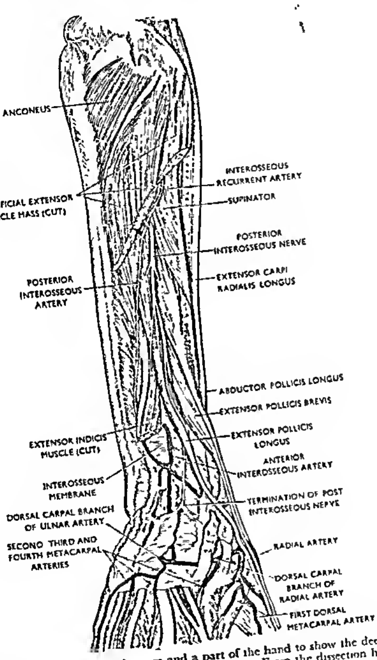


Fig. 819. The dissection of the dorsum of the right hand. Note the distribution of the radial and the ulnar nerves. With kind permission from Lederle Laboratories Ltd. Drawn by Mr. Paul. Peck.

Posterior interosseous nerve. The posterior interosseous nerve arises from the radial nerve opposite the front of the lateral epicondyle of the humerus and the immediately enters into the substance of the supinator muscle and passes between its two planes of fibres. As it passes between the two planes of fibres of the supinator muscle it winds round the lateral side of the radius to the back of the forearm. Then it leaves the supinator muscle and by dividing into muscular branches it becomes much reduced in size which descends downwards between the deep and the superficial groups of muscles and then accompanies the posterior interosseous artery. Reaching the lower border of the extensor pollicis brevis muscle it passes beneath

extensor pollicis longus muscle and lies on the back of the interosseous membrane. ...ally it reaches the back of the carpus where it forms a gangliform swelling (not ...rue ganglion) from which twigs are given to the ligaments and articulations of ...e carpus.



...ig. 850. The dorsum of the right forearm and a part of the hand to show the deep muscles and the ...osterior interosseous nerve and the dorsal carpal networks. From the dissection hall, N. R. Sircar Medical College, Calcutta; with kind permission from the Prof. of Anatomy.

Distribution. Before entering into the supinator muscle it gives muscular branches to the extensor carpi radialis brevis and to the supinator muscle. Then as it passes through the supinator muscle it provides an additional branch to the same muscle. After its exit from the supinator it divides into three short branches, one each for extensor digitorum, extensor digiti minimi and extensor carpi ulnaris and two long branches, a medial, supplying the extensor pollicis longus and the extensor indicis and a lateral, supplying the abductor pollicis longus and the extensor pollicis brevis.

Injury to the radial nerve. The radial nerve, having its direct relation with the spiral groove of the humerus, is frequently injured in case of fracture of the middle-third of the humerus. It may be completely severed into two or it may be grossly lacerated and in either of the two conditions the following results will be noticed:

(1) *Wrist drop.* The hand is flexed at the wrist joint due to paralysis of the extensor muscles.

(2) Extension of the proximal phalanx is impossible due to the paralysis of the extensor digitorum but extension of the middle and terminal phalanges is possible because the interossei and the lumbricales do this movement.

The only exception to this is the distal and proximal phalanges of the thumb which cannot be extended because the extensor pollicis longus et brevis are affected and which are extended by the same muscles and not by the interossei.

(3) Extension of the elbow joint is impossible because the triceps is paralysed.

(4) Supination of the forearm is impossible when the forearm is made to extend due to paralysis of the supinator.

(5) Supination of the forearm is possible when the elbow is flexed because biceps brachii is a strong supinator of the forearm when the elbow is bent.

(6) Anaesthesia of the lateral part of the dorsum of the hand.

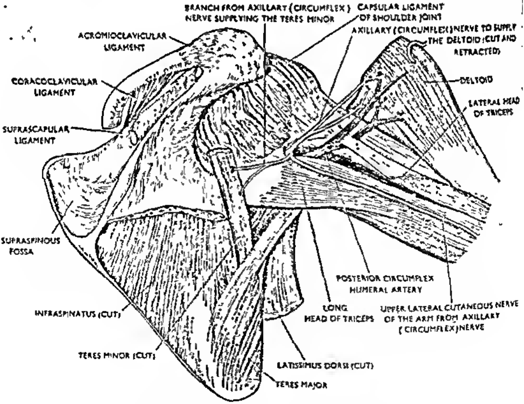


Fig. 851. The dorsal aspect of the scapulo-humeral region. The supraspinatus, a part of the infraspinatus, teres major, latissimus dorsi and the deltoid have been removed. Note the distribution of the axillary nerve. From the dissection hall, N. R. Sircar Medical College, Cal.; with kind permission from the Prof. of Anatomy.

Axillary (Circumflex) nerve. It arises from the posterior cord of the brachial ılexus and *derives its fibres from the fifth and sixth cervical nerves. At first it lies* ıehind the third part of the axillary artery, in front of the subscapularis muscle and ateral to the radial nerve. Then reaching the lower border of the subscapularis nuscle it inclines backwards to come into close relation with the capsular ligament f the shoulder joint. Then it accompanies the posterior humeral circumflex artery nd enters into the quadrangular space which is bounded above and in front by the ubscapularis, above and behind by the teres minor, laterally by the surgical neck f *the humerus, medially by the long head of the triceps and below by the teres major.* 'hen it gives a twig to the shoulder joint and ends by dividing into anterior and osterior branches.

The *anterior branch* accompanies the posterior humeral circumflex artery and rinds round the surgical neck of the humerus and passes deep to the deltoid muscle. n its course it provides muscular branches to the anterior part of the deltoid muscle. ts terminal filaments ierce the deltoid muscle nd supply the skin in ront of the lower part of his muscle.

The *posterior branch upplies* the posterior part f the deltoid and the eres minor muscle. The ıerve to the teres minor ıresents a gangliform welling (Pseudo-ganglia ıecause there are no ıerve cells in it) which s its characteristic. After upplying the posterior ıart of the deltoid it ıierces the muscle and he deep fascia and then s continued as the *upper ateral cutaneous nerve of the ırm* which supplies the kin covering the back of he deltoid and the long ıead of the triceps.

Injury to the axillary circumflex) nerve. Due to ts intimate relation to the urgical neck of the hunerus it is often involved n the fracture of the urgical neck of the hunerus and in dislocation f the shoulder joint. Severance of this nerve auses paralysis of the leltoid muscle. Consequently abduction of the houlder joint becomes mpossible and there is ınaesthesia of the skin covering the lower part of he deltoid. Supraspinatus

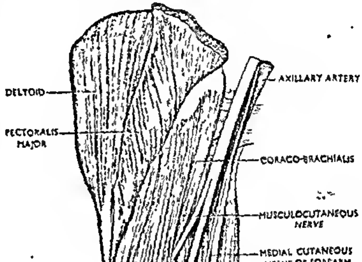


Fig. 852. The front and the medial aspects of the right arm. Note the positions of the nerves. From the dissection hall, N. R. Sircar Medical College, Cal.; with kind permission from the Prof. of Anatomy.

which is also an abductor of the shoulder joint cannot cause abduction because it acts in conjunction with the deltoid.

Thoracodorsal Nerve. (*Nerve to the latissimus dorsi*)—It arises from the posterior cord of the brachial plexus and descending downwards in front of the subscapularis muscle accompanies the muscular branch of the subscapular artery to reach the latissimus dorsi.

The **upper** and the **lower subscapular nerves.** They usually arise by a common trunk from the posterior cord of the brachial plexus. The *upper subscapular nerve* enters the subscapularis muscle opposite the middle of the subscapular fossa whereas the *lower subscapular nerve* enters the muscle close to its lower border and before piercing the muscle gives a twig which crosses the gap between the subscapularis and the teres major and finally ends by entering into the teres major muscle which it supplies.

The musculocutaneous nerve. The musculocutaneous nerve supplies the coracobrachialis, biceps brachii and the medial half of the brachialis (the lateral half being supplied by the radial nerve) and the skin on the lateral side of the forearm

The musculocutaneous nerve of the arm arises from the lateral cord of the brachial plexus below the lower border of the pectoralis minor muscle and derives its fibres from the fifth, sixth and seventh cervical nerves. At first it lies on the lateral side of the third part of the axillary artery and the beginning of the brachial artery. Then it pierces the coracobrachialis muscle and passes obliquely downwards between the biceps brachii and the brachialis muscle to the lateral side of the arm and a little below the elbow it pierces the deep fascia on the lateral side of the tendon of the biceps and then is continued downwards as the lateral cutaneous nerve of the forearm.

The lateral cutaneous nerve of the forearm. It passes downwards behind the cephalic vein and supplies the skin of the lateral half of the forearm. In its course through the forearm it gives out a series of lateral branches which wind round the radial border of the forearm and communicate with the posterior cutaneous nerve of the forearm. Immediately above the wrist joint it lies in front of the radial artery and then divides into anterior and posterior terminal filaments which pierce the deep fascia. The posterior terminal filament accompanies the radial artery and communicates with the radial nerve; the anterior filament supplies the skin of the ball of the thumb and communicates with the palmar cutaneous branch of the median nerve.

The nerve to the coracobrachialis arises from it before it pierces that muscle; the branch to the biceps and the brachialis are given out during its course between these muscles. The branch which supplies the brachialis muscle also provides an articular twig to the elbow joint and a nutrient filament which enters the humerus at the nutrient foramen along with the nutrient artery.

N.B.—The musculocutaneous nerve presents frequent irregularities. Some of its fibres may pass along with the median nerve, or some fibres of the latter may come through this nerve. It may pass behind the coracobrachialis instead of piercing it or it may pass behind the biceps brachii muscle. Sometimes the pronator teres may be supplied by a branch from it Sometimes it replaces the digital branches of the radial nerve for the thumb finger.

The median nerve. The median nerve supplies all the flexor muscles of the forearm exept the flexor carpi ulnaris and the medial half of the flexor digitorum profundus, the muscles of thenar eminence (Abductor pollicis brevis, opponens pollicis and the flexor pollicis brevis) and the first and second lumbricales and the skin of the lateral side of the palm and the digits up to first three and a half digits.

It begins in the axilla and after a considerable course in the arm and the forearm it ends in the palm of the hand by dividing into digital nerves.

Median nerve in the axilla and the arm. In the axilla the median nerve arises by lateral and medial roots from the corresponding cords of the brachial plexus and the

two roots unite to form the nerve trunk either in front of or on the lateral side of the third part of the axillary artery. It derives its fibres from fifth, sixth, seventh, and eighth cervical and the first thoracic nerve. In the arm the median nerve at first lies on the lateral side of the brachial artery and opposite the insertion of the coracobrachialis it crosses either superficial or deep to the brachial artery and lies on its medial side. Maintaining this relation it enters the cubital fossa. Throughout its course in the arm it is superficial being covered only by the skin, superficial and the deep fasciae.

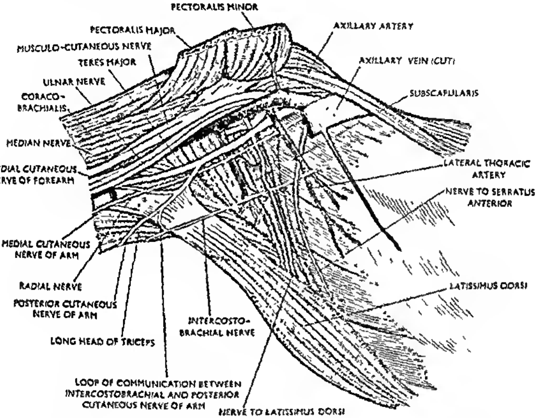


Fig. 853. The brachial plexus of nerves with the axillary vessels The axillary vein has been partly removed. From the dissection hall, N. R. Sircar Medical College, Cal, with kind permission from the Prof. of Anatomy

Branches. No branches are given out in the axilla.
Branches in the arm one only.
Nerve to the pronator teres may arise from it in the lower arm.

Median nerve in the forearm. In the upper part of the forearm the median nerve lies in the cubital fossa on the medial side of the terminal portion of the brachial artery and then descends downwards between the two heads of the pronator teres and crosses in front of the ulnar artery being separated from it by the deep head of the pronator teres. It then passes beneath the tendinous arch connecting the humeroulnar and the radial heads of the flexor digitorum superficialis and then descends in between the flexor digitorum superficialis in front and the flexor digitorum profundus behind to the lower part of the forearm where about 2 inches above the flexor retinaculum it is crossed by the radial head of the flexor digitorum superficialis and lies in between the flexor carpi radialis and palmaris longus. The latter muscle partly overlaps it. It then enters the palm under cover of the flexor retinaculum.

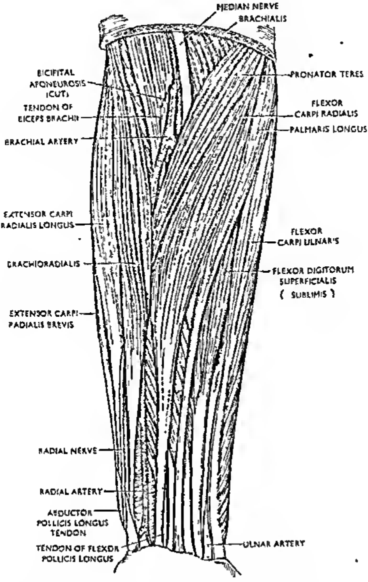


Fig. 831. The front of the left forearm Note the position of the median nerve in the cubital fossa. From the dissection hall, N. R. Sircar Medical College, Cal; with kind permission from the Prof. of Anatomy.

Branches in the forearm—

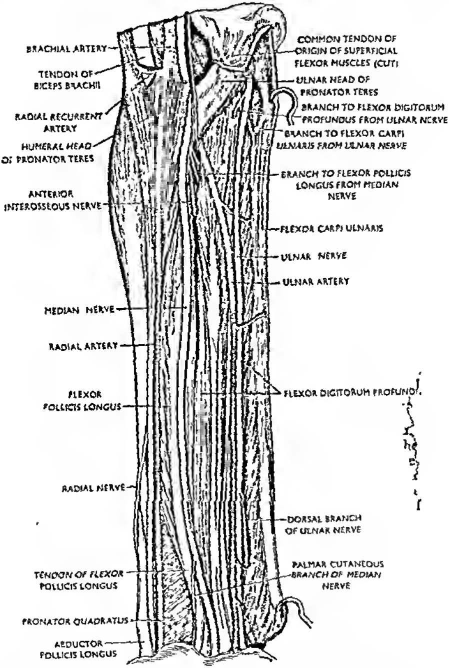
(1) *Muscular branches.* The muscular branches supply all the superficial group of the flexor muscles except the flexor carpi ulnaris, i.e., pronator teres, the flexor carpi radialis, palmaris longus and the flexor digitorum superficialis.

(2) *Anterior interosseous.* It supplies the flexor pollicis longus, the pronator quadratus and the lateral half of the flexor digitorum profundus.

(3) *Palmar.* The palmar cutaneous branch divides into medial and lateral branches and by its lateral braoch it supplies the skin of the thenar eminence and communicates with the anterior branch of the lateral cutaneous nerve of the forearm, by its medial branch it supplies the skin of the palm and communicates with the palmar branch of the ulnar nerve.

(4) *Articular branch to the elbow joint.* It arises from the median nerve as it descends in front of the elbow joint to enter into the cubital fossa.

MEDIAN NERVE IN THE PALM OF HAND. The median nerve enters the palm of ıe hand beneath the flexor retinaculum of the hand and then becomes enlarged ıd flattened which lies upon the flexor tendons and divides into lateral and medial ranches.



;. 855. The front of the right forearm after removal of some of the superficial flexor mus the positions of the ulnar and median nerves. From the dissection hall, N. R. Sircar College, Cal.; with kind permission from the Prof. of Anatomy.

The lateral branch provides a stout muscular branch for the musc enar eminence (abductor pollicis brevis, opponens pollicis and the flex evis) then divides into three palmar digital nerves, two of which suppl les of the thumb finger and the interphalangeal joints of the same and the third pplies the first lumbricalis muscle and then is distributed to the radial side of the dex finger.

The medial branch divides into two palmar digital nerves, one of which supplies the second lumbricalis and then continues downwards towards the cleft between the middle and the index fingers where it divides into two collateral branches which supply the contiguous sides of the index and the middle fingers. The second palmar digital branch sometimes supplies the third lumbricalis (when it is not supplied by

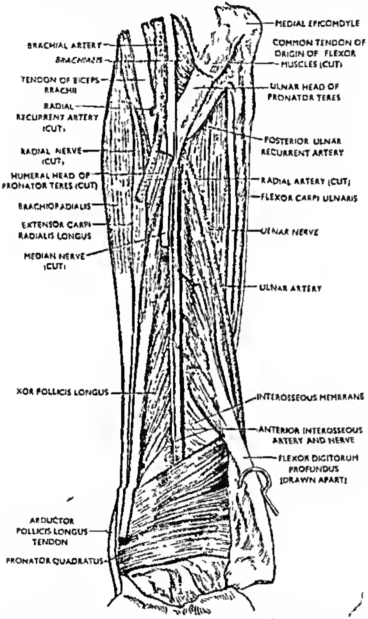


Fig. 85

Fig. 856. The deep muscles on the front of the right forearm. Note the position of the anterior interosseous vessels and nerve. From the dissection hall, N. R. Sircar Medical College, Cal.; with kind permission from the Prof. of Anatomy.

Each digital nerve opposite the metacarpophalangeal joint provides a dorsal branch which passes backwards and communicates with the radial nerve to supply the digits and is then continued downwards to the pulp of the finger (lying in front of the digital artery) where it divides into two branches, one supplies the pulp of the finger and the other ramifies in the nail bed. Each digital branch gives an articular twig to the corresponding metacarpophalangeal joint and also supplies the interphalangeal joints.

Injury to the median nerve. *Injury to the nerve at the elbow* will cause paralysis of the pronator teres, palmaris longus, flexor carpi radialis, flexor digitorum superficialis, pronator quadratus, lateral half of the flexor digitorum profundus, thenar muscles and the first and the second lumbricales.

Pronation of the forearm is impossible due to paralysis of the pronator muscles. Flexion of the wrist joint will be partially done by the flexor carpi ulnaris. Index finger cannot be flexed at all except at the metacarpophalangeal joint, even though, the interossei are not paralysed. Opposition action of the thumb finger will be lost and its terminal phalanx cannot be flexed. There is also anaesthesia of the skin of the palmar aspect of the lateral 3½ fingers.

Injury to the nerve at the wrist will cause paralysis of the thenar muscles and the first and second lumbricales. Opposition action (as in pinching) of the thumb will be lost and there will be associated anaesthesia as above.

The ulnar nerve. The ulnar nerve arises from the medial cord of the brachial plexus and derives its fibres from the seventh and the eighth cervical and the first thoracic nerves. From its origin in the axilla it descends downwards on the medial side of the axillary artery lying between it and the axillary vein and then runs downwards on the medial side of the brachial artery as far as the middle of the arm where it pierces the medial intermuscular septum along with the superior ulnar collateral artery and together run downwards in front of the medial head of the triceps brachii to the interval between the medial epicondyle of the humerus and the olecranon of the ulna. Opposite the elbow joint it lies in a groove behind the medial epicondyle together with the superior ulnar collateral artery and then enters the forearm between the two heads of the flexor carpi ulnaris.

In the forearm it lies in front of the flexor digitorum profundus and is covered by the flexor carpi ulnaris opposite its upper three-fourths, and in the lower one-fourth, it is covered only by the skin and the fasciae. In the upper one-third of the forearm, the ulnar artery lies at a considerable distance from it but in the lower two-thirds of the forearm, it lies in close contact with the artery being placed on its medial side. Then it enters the palm of the hand in front of the flexor retinaculum, lateral to the pisiform bone and on the medial side of the ulnar artery. In the palm of the hand it ends by dividing into the superficial and deep branches.

(About 5 cm. above the wrist joint it gives out its dorsal branch).

Branches—

(a) *Articular.* It supplies the elbow joint.

(b) *Muscular.* It arises in the upper-third of the forearm below the medial epicondyle of the humerus and ends by supplying the flexor carpi ulnaris and the medial half of the flexor digitorum profundus.

(c) *Dorsal.* It arises from the ulnar nerve about 5 cm. above the wrist joint and supplies the skin of the contiguous sides of the ring and the little fingers and also the medial side of the little finger on the dorsum of the hand.

(d) *Palmar cutaneous.* It supplies the skin of the medial side of the palm of the hand.

(e) *Superficial terminal.* See ulnar nerve in the plam of the hand.

(f) *Deep terminal branch.* See ulnar nerve in the palm of the hand.

Ulnar nerve in the palm of the hand. The ulanr nerve enters the palm of the hand in front of the flexor retinaculum, lateral to the pisiform bone and on the

medial side of the ulnar artery and then it divides into superficial and the deep branches.

The *superficial branch* sends out a twig which supplies the palmaris brevis muscle and the skin on the medial side of the hand and then divides into two palmar digital nerves. One supplies the skin on the medial side of the little finger and the other gives a communicating branch to the median nerve and then divides into two collateral branches which supply the contiguous sides of the little and the ring fingers. Each digital branch opposite the metacarpophalangeal joint gives out a dorsal branch which communicates with the dorsal branch of the ulnar nerve. At the tip of the finger it divides into two branches, one supplies the pulp of the finger and the other the nail bed.

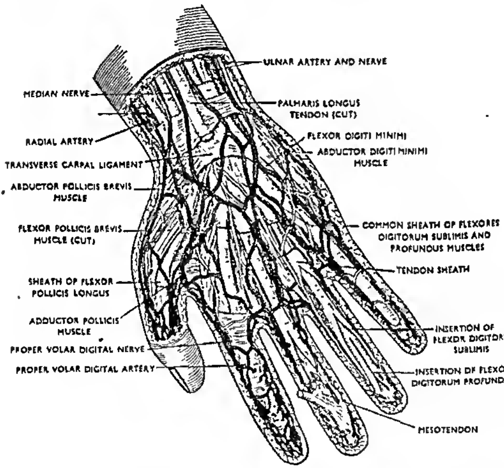


Fig. 857. The palmar aspect of the right palm to show the superficial vessels and nerves. With kind permission from Lederle Laboratories Ltd. Drawn by Mr. Paul Peck.

The *deep branch* passes in between the abductor digiti minimi and flexor digiti minimi and then pierces the opponens digiti minimi in company with the deep branch of the ulnar artery and then follows the course of the deep palmar arch deep to the flexor tendons to the radial side of the palm where it ends by supplying the adductor pollicis and the first dorsal interosseous muscles. In its course through the palm it supplies all the interossei muscles and the third and the fourth lumbricalis muscles. It also supplies a few twigs to the wrist joint.

N.B.—The third lumbricalis may be supplied by a branch from the median nerve when the branch from the ulnar nerve may be wanting or it may have double nerve supply, one from the ulnar median nerve. Usually it is supplied by the ulnar nerve.

Injury to the ulnar nerve. *Division of the nerve at the elbow* will cause paralysis of the flexor carpi ulnaris, medial half of flexor digitorum profundus, hypothenar muscles, all the interossei and the third and the fourth lumbricales and the adductor pollicis.

Flexion of the terminal phalanx of the little finger is impossible and also adduction of the thumb is impaired. Adduction and abduction of other fingers will also be impaired.

Up and down storke in writing is caused by the interossei and the lumbricales and this movement will be completely lost in case of the ring and little fingers, and partially, in case of middle and index fingers. There will be cutaneous anaesthesia of the little and the medial side of the ring finger.

Injury to the nerve at the wrist will cause paralysis of the hypothenar muscles, the interossei and the third and the fourth lumbricales. The dorsal branch of the ulnar nerve being escaped there will be no anaesthesia on the back of the little and the ring fingers.

VENTRAL RAMI OR DIVISIONS OF THE THORACIC NERVES

The ventral rami (Anterior primary rami) of the thoracic nerves are twelve in number and each of them makes its exit from the intervertebral foramen below the corresponding vertebra. The upper eleven pairs of nerves occupy the corresponding intercostal spaces and are known as the **intercostal nerves** whereas the twelfth nerve lies below the corresponding vertebra and the rib and is known as the **subcostal nerve.** The first three intercostal nerves and the twelfth thoracic or the subcostal nerve differ from the others in their course and distribution. The fourth, the fifth and the sixth intercostal nerves are similar in their course and distribution and they remain confined to the thoracic wall and as such they are referred to as the **typical intercostal nerve.** The seventh, eighth, ninth, tenth and the eleventh intercostal nerves differ from the typical intercostal nerves in their course and mode of distribution. All of them proceed to the abdominal wall from the thoracic wall. In the thoracic part of their course they have the same course and distribution with the typical intercostal nerves.

The first thoracic nerve. The ventral ramus of the first thoracic nerve leaves the intervertebral foramen below the neck of the first rib and soon divides into a larger, upper or superior branch and a smaller, lower or inferior branch. The *superior branch* ascends upwards in front of the neck of the first rib lateral to the superior intercostal artery and enters into the neck behind the first part of the subclavian artery and then joins with the eighth cervical nerve to form the lowest trunk of the brachial plexus.

The *inferior branch* forms the true intercostal nerve and runs forwards between the pleura and the inferior surface of the first rib and reaches the intercostal space close to the first costal cartilage. Further anteriorly it crosses the internal thoracic (mammary) vessels and then turns forwards to become anterior cutaneous branch which supplies the skin below the clavicle. In its course it supplies the intercostal muscles of the first intercostal space. Its lateral cutaneous branch is usually absent and when present, it communicates either with the intercostobrachial nerve or with the medial cutaneous nerve of the arm.

The second intercostal nerve occupies the second intercostal space and has a similar course like that of the first intercostal nerve. It provides a *lateral cutaneous branch* opposite the mid-axillary line which pierces through intercostal muscles and passes laterally to the arm as the *intercostobrachial nerve* which communicates with the medial cutaneous nerve of the arm and descends along the posteromedial part of the arm as far down as the elbow and supplies the skin and the subcutaneous tissues in this region. It also provides a communicating twig to the first thoracic nerve which joins in the brachial plexus and also with the lateral cutaneous branch

of the third intercostal nerve. In addition it has the usual muscular and anterior cutaneous branches.

The third intercostal nerve has the same type of course and distribution like the typical intercostal nerve but it differs from them in that the posterior branch *of its lateral cutaneous branch passes to the arm and supplies the skin on the medial* side of the upper arm.

Typical intercostal nerve. The typical intercostal nerve is the anterior primary rami of the fourth, fifth and the sixth thoracic nerves. After its exit from the intervertebral foramen each lies between the internal (posterior) intercostal membrane and the costal pleura. Then it pierces the intercostal membrane and occupies the costal groove where it lies below the intercostal vessels and between the external and internal intercostal muscles. Maintaining this relation it is continued forwards as far as the mid-axillary line where it gives off its lateral cutaneous branch. It then pierces the internal intercostal muscle and passes forwards through its substance as far as the anterior end of the bony rib where it emerges into the deep aspect of the internal intercostal muscle and lies between it and the costal pleura. In its further course forwards it crosses the transversus thoracis (sternocostalis) muscle and the internal thoracic (mammary) artery and then bending sharply forwards it pierces the internal intercostal muscle, external (anterior) intercostal membrane, the pectoralis major muscle and its fascia and then becomes the anterior cutaneous nerve of the chest wall, which supplies the skin in this area.

N.B.—Only the upper six nerves maintain this typical distribution. The lower five nerves are continued into the anterior abdominal wall where they lie in between the transversus abdominis and the obliquus internus abdominis and finally, by piercing the rectus sheath and the muscle they become cutaneous.

The intercostal nerves in their course, in addition to anterior and lateral cutaneous branches, provide muscular branches for the internal and external intercostal muscles.

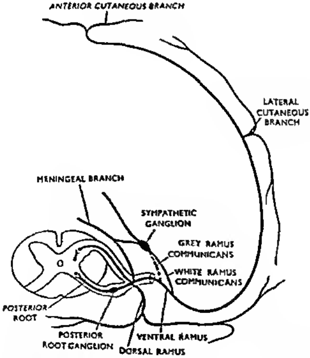


Fig. 858. A thoracic spinal nerve. Note the distribution of a intercostal nerve.

Lateral cutaneous branch of the intercostal nerves. The first intercostal nerve has no lateral cutaneous branch. The lateral cutaneous branch of the second intercostal nerve passes to the arm as the intercostobrachial nerve. The lateral cutaneous branches from third to the sixth intercostal nerves become superficial by piercing the external intercostal muscle close to the lower margin of the pectoralis minor. Each nerve divides into anterior and posterior branches. The anterior branch winds round the lower border of the pectoralis major and passes medially to supply the skin on the lateral aspect of the pectoralis major. The posterior branch passes backwards and ends by supplying the skin on the postero-lateral aspect of the thoracic wall.

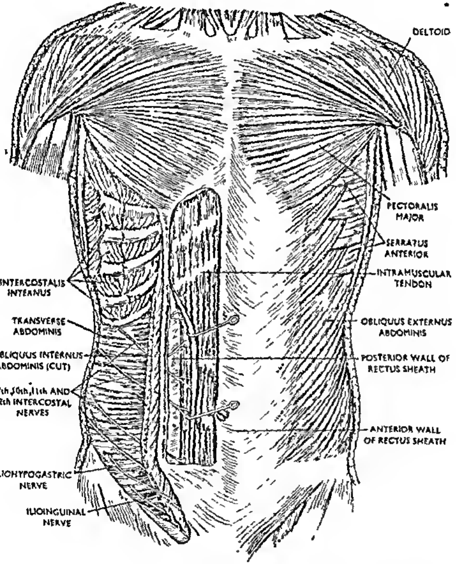


Fig. 959. The superficial flat muscles of the chest wall and abdomen together with the opened-up rectus sheath to show the rectus abdominis muscle and the lower intercostal nerves.

The seventh, eighth, ninth, tenth and the eleventh intercostal nerves differ from the typical intercostal nerves in having their additional course and distribution in the anterior abdominal wall. In the thoracic wall they have the same course and distribution with the typical intercostal nerves. Each of these nerves enters into the abdominal wall by passing between the attachments of the

diaphragm muscle and the transversus abdominis to the costal cartilages. In the abdominal wall they run downwards and forwards between the transversus abdominis and the obliquus internus abdominis (neurovascular plane of the abdominal wall) and then enter into the rectus sheath by piercing its posterior wall. Within the rectus sheath they lie between the muscle and its posterior sheath and finally divides into medial and lateral branches, the latter ending in the rectus abdominis muscle while the former after supplying the same muscle pierces through the anterior wall of the sheath and finally becomes cutaneous. They also provide muscular branches to the transversus abdominis, obliquus externus and internus abdominis and to the parietal peritoneum and to the extra-peritoneal tissue. The seventh nerve supplies the skin in the region of the xiphoid process, the eighth and the ninth nerves between the xiphoid process and the umbilicus, the tenth nerve supplies the skin in the region of the umbilicus while the eleventh nerve supplies the skin immediately below the umbilicus.

The subcostal nerve. It makes its exit from the intervertebral foramen between the last thoracic and the first lumbar vertebrae and soon gains the lower border of the last rib and then passes laterally behind the upper part of the psoas major muscle. *It enters the abdomen by passing below the lateral arcuate ligament* and further passes laterally and downwards in front of the quadratus lumborum muscle. Then *it pierces the transversus abdominis muscle by passing behind the kidney and gains the neurovascular plane* (space between the transversus abdominis and the obliquus internus abdominis). Reaching the anterior abdominal wall it gradually approaches the median plane and *enters into the rectus sheath by passing in front of the rectus abdominis muscle.* Its terminal filaments pierce through the anterior wall of the rectus sheath and become cutaneous (anterior cutaneous) mid-way between the umbilicus and the symphysis pubis.

Its branches are muscular, and cutaneous. The muscular branches supply the transversus abdominis, obliquus externus and internus abdominis, rectus abdominis and pyramidalis. Its cutaneous branches are anterior cutaneous and lateral cutaneous.

The anterior cutaneous branches supply the skin in the region mid-way between the umbilicus and the symphysis pubis. Its lateral cutaneous branch runs laterally and downwards between the transversus abdominis and the internal oblique and then becomes superficial about 2 inches above the iliac crest and the same distance behind the anterior superior iliac spine. It then runs further downwards and laterally across the iliac crest to the gluteal region and ends by sypplying the skin and the fasciae opposite the front of the greater trochanter of the femur.

THE LUMBAR PLEXUS AND ITS BRANCHES

The lumbar plexus is situated within the substance of the psoas major muscle and is formed in front of the transverse processes of the lumbar vertebrae by the union of the anterior primary rami of the upper three lumbar nerves and by the greater part of the anterior primary ramus of the fourth lumbar nerve. The first lumbar nerve is usually joined by a branch from the last thoracic nerve. The arrangement of the plexus is as follows:

The first lumbar nerve receives a branch from the last thoracic nerve and then divides into superior and inferior branches. The superior branch splits into iliohypogastric and ilioinguinal nerves. The inferior branch supplemented by a twig from the second lumbar nerve forms the genitofemoral nerve. The remainder of the second, third and the fourth lumbar nerves divide into a ventral and a dorsal branch. The ventral branches of the second, third and the fourth lumbar nerves unite to form the obturator nerve. The accessary obturator nerve arises from the anterior primary rami of the third and fourth lumbar nerves. The dorsal branches of the second and the third nerves further divide into smaller and larger branches; the smaller branches unite to form the lateral femoral cutaneous nerve of the thigh

and the larger branches unite with the dorsal branch of the fourth lumbar nerve to form the femoral nerve.

Iliohypogastric nerve. It arises from the anterior primary ramus of the first lumbar nerve and emerges from the lateral border of the psoas major to the front of the quadratus lumborum muscle from which it is separated by the anterior layer of the lumbar fascia. It then runs obliquely downwards and forwards between the anterior layer of the lumbar fascia and the posterior surface of the kidney and descends downwards, forwards and laterally to reach a point immediately above the iliac crest and then perforates the transversus abdominis muscle and finally divides into two branches, lateral and anterior.

The lateral cutaneous branch pierces the internal and external oblique muscles immediately above the iliac crest and then passes to the gluteal region to supply the skin on the anterior part of the buttock.

The anterior branch runs between the transversus and obliquus internus abdominis muscle, supplies twigs to these muscles and then pierces the obliquus internus at a point about 2 cm. internal to the anterior superior iliac spine and then pierces the aponeurosis of the external oblique muscle about 3 cm. above the superficial inguinal ring and ends by supplying the skin of the abdomen above the pubis.

It communicates with the last thoracic and the ilioinguinal nerves.

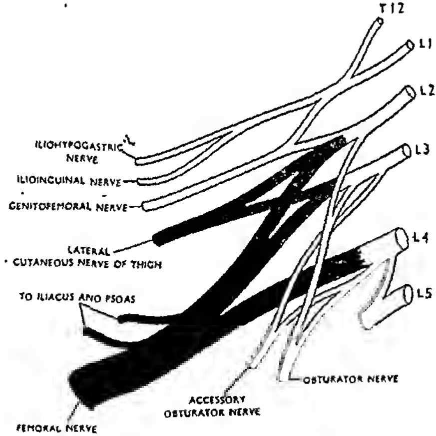


Fig. 869. A schematic drawing of the lumbar plexus of nerves and its branches.

Ilioinguinal nerve. It arises from the *anterior primary ramus of the first* lumbar nerve and emerges from the lateral border of the psoas major muscle immediately below the iliohypogastric nerve. It descends obliquely between the posterior surface of the kidney and the quadratus lumborum with its covering fascia and perforates the transversus abdominis at the anterior part of the iliac crest. It

then runs downwards between the transversus and the internal oblique, pierces the latter, supplies twig to this muscle and then accompanies the spermatic cord in the inguinal canal and comes out through the superficial inguinal ring. Finally it is distributed to the skin of the root of the penis, upper part of the scrotum and the adjoining part of the inner side of the thigh.

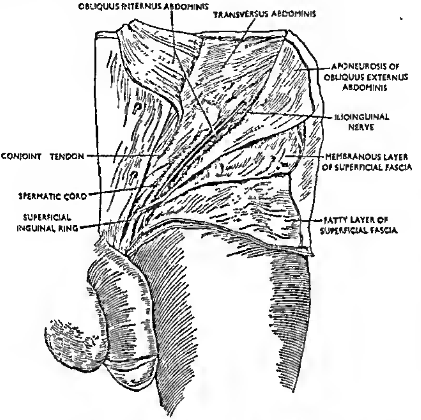


Fig. 861. The dissection of the left inguinal canal Note the position of the ilioinguinal nerve. From the dissection hall, N. R. Sircar Medical College, Cal.; with kind permission from the Prof. of Anatomy.

Genitofemoral. The genitofemoral nerve arises from the anterior primary rami of the first and second lumbar nerves and descends obliquely downwards through the psoas major muscle, and opposite the level of the third or fourth lumbar vertebra, it pierces the muscle and descends in front of the same under cover of the parietal peritoneum. It crosses posterior to the ureter, and a little above the inguinal ligament, it divides into genital and femoral branches.

The *genital branch* crosses the external iliac vessels and then enters the deep inguinal ring in company with the vas deferens in male, and with the round ligament of the uterus in female. In male, it supplies the cremaster muscle and the upper part of the skin of the scrotum. In the female, it supplies the fibro-fatty tissue and the skin in front of the mons pubis.

The *femoral branch* descends on the lateral side of the external iliac artery and crosses the deep circumflex iliac artery and then passes beneath the inguinal ligament to enter the femoral sheath and at first lies on the lateral side of the femoral artery and then in front of it. It pierces the anterior layer of the femoral sheath and the fascia lata and ends by supplying the skin in front of the upper part of the femoral triangle. It communicates with the intermediate cutaneous nerve of the thigh and gives a twig to the femoral artery.

Muscular branches. Muscular branches supply the psoas major et minor, the iliacus and the quadratus lumborum. The psoas minor receives its fibres from the first lumbar nerve, the psoas major and the iliacus from the second, third and the fourth lumbar nerves and the quadratus lumborum from the twelfth thoracic and from the first to the fourth lumbar nerves.

Lateral cutaneons nerve of the thigh. It arises from the dorsal divisions of the anterior primary rami of the second and the third lumbar nerves and passes obliquely behind the psoas major muscle and emerges to the iliac fossa from the lateral border of the psoas major muscle. In the iliac fossa it lies obliquely on the iliacus muscle and crosses posterior to the caecum, on the right side, and the lower part of the descending colon, on the left side, being separated from them by fascia iliaca and the peritoneum. It then emerges to the thigh behind the lateral end of the inguinal ligament and between the anterior superior and the anterior inferior iliac spines; it then passes either superficial to the proximal end of the sartorius muscle or through its fibres to gain the upper anterolateral aspect of the thigh where it divides into anterior and posterior branches behind the deep fascia.

The *anterior branch* becomes superficial about 4 inches below the anterior superior iliac spine and then supplies the skin on the anterolateral aspect of the thigh as far as the knee joint. Its terminal filaments communicate with the intermediate and the medial cutaneous nerves (from the anterior division of the femoral nerve) of the thigh and the infrapatellar branch of the saphenous nerve to form a plexiform network, the *patellar plexus.*

The *posterior branch* becomes superficial a little above the anterior branch and then divides into branches which pass backwards and supply the skin on the lower and lateral part of the gluteal region and the lateral aspect of the thigh from the level of the greater trochanter to the middle of the thigh.

Femoral nerve. The femoral nerve arises from the dorsal branches of the anterior primary rami of the second, third and the fourth lumbar nerves. From its origin it descends through the fibres of the psoas major muscle and emerges at the lower part of the lateral border of this muscle to reach the interval between it and the iliacus where the nerve lies deep to the fascia iliaca. Maintaining this relation it passes to the thigh behind the inguinal ligament, lies on the lateral side of the femoral artery and then divides into anterior and posterior branches. The *nerve to the pectineus* arises from it before its division, and in the abdominal cavity it provides muscular branches for the iliacus.

A. Anterior division:

(*i*) *Cutaneous.* Intermediate and the medial cutaneous nerves of the thigh.
(*ii*) *Muscular.* To the sartorius (through the intermediate cutaneous nerve).

B. Posterior division:

(*i*) *Cutaneous.* Saphenous nerve.
(*ii*) *Muscular.* To vastus lateralis, medialis and the intermedius and to the rectus femoris.

N.B.—Articular branches are also given from the femoral nerve to the hip and the knee joints but these branches are not directly coming from the nerve trunk. They are distributed to the joints as follows: The nerve to the rectus femoris supplies a twig to the hip joint; the nerve to the vastus medialis, intermedius and the lateralis, each provides a twig for the knee joint. The nerve to the vastus intermedius also provides a twig for the articularis genu muscle.

The nerve to the pectineus arises from the medial side of the femoral nerve immediately below the inguinal ligament and passes medially beneath the femoral sheath and ends by piercing the anterior surface of the pectineus muscle.

Intermediate cutaneons nerve of the thigh. The intermediate cutaneous nerve of the thigh arises from the anterior division of the femoral nerve and pierces

the deep fascia about three inches below the inguinal ligament either as two branches or as a single trunk which soon divides into two branches—lateral and medial. It supplies the skin in front of the thigh as low as the knee joint. The lateral branch communicates with the femoral branch of the genitofemoral nerve. The terminal filaments of the two branches end in the patellar plexus. The lateral branch sometimes pierces the sartorius muscle after its origin.

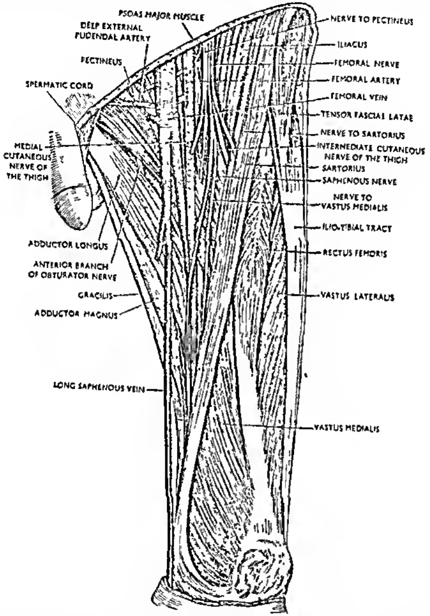


Fig. 862. The antero-medial aspect of the left thigh to show the muscles and branches from the femoral nerve. From the dissection hall, N. R. Sircar Medical College, Cal.; with kind permission from the Prof. of Anatomy.

Medial cutaneous nerve of the thigh. It arises from the anterior division of the femoral nerve and it first lies on the lateral side of the femoral artery deep to fascia lata. Opposite the apex of the femoral triangle, it crosses in front of the femoral artery from lateral to the medial side and then divides into anterior and posterior

branches. Before division some of its filaments either pierce the fascia lata or pass through the saphenous opening and supply the skin on the medial side of the thigh.

The anterior branch passes downwards lying in front of the sartorius muscle deep to the fascia lata, and opposite the junction of the middle with the lower-third of the thigh, it pierces the fascia lata and then divides into two branches. One supplies the skin on the lower part of the medial side of the thigh as low as the medial side of the knee joint. The other goes to the lateral side of the patella and communicates with the infrapatellar branch of the saphenous nerve and the lateral and intermediate cutaneous nerves of the thigh to form the *patellar plexus.*

The *posterior branch* descends downwards under the deep fascia along the posterior border of the sartorius muscle to reach the upper part of the knee joint where it pierces the deep fascia and gives out filaments which join in the patellar plexus and also supply the skin in this region. It then descends downwards behind the medial condyle of the femur to reach below the knee joint where it ends by supplying the skin on the upper part of the medial side of the leg. In the lower part of the adductor canal it gives out some filaments which pass beneath the sartorius to join in the *sub-sartorial plexus.* The sub-sartorial plexus is a plexiform network of nerves formed by branches from the anterior division of the obturator nerve, the saphenous nerve and branches from the posterior branch of the medial femoral cutaneous nerve.

Saphenous nerve. The saphenous nerve is the longest cutaneous branch from the femoral nerve and arises from its posterior division. In the femoral triangle, it lies on the lateral side of the lower part of the femoral artery and maintaining this relation it enters the adductor canal where it crosses in front of the artery from lateral to the medial side; and in the lower part of the canal, accompanying the saphenous branch of the inferior genicular artery, it pierces the aponeurotic roof of the canal. It then descends vertically downwards under cover of the sartorius muscle to the medial side of the knee joint where it pierces the deep fascia between the sartorius and the gracilis and becomes subcutaneous. It then accompanies the long saphenous vein, and lying in front of the vein, it descends downwards along the medial border of the tibia to reach the lower part of the leg where it divides into two branches. One branch descends further downwards along the medial margin of the tibia to reach the medial aspect of the ankle joint where it ends by supplying the skin in the region. The other branch passes downwards along with the long saphenous vein in front of the ankle joint and then passes along the medial side of the foot to reach the medial side of the ball of the great toe where it ends by communicating with the medial branch of the musculocutaneous nerve.

Branches:

(1) Opposite the adductor canal it gives out a branch which joins the sub-sartorial plexus.
(2) Below the adductor canal it gives out the infrapatellar branch which pierces the sartorius muscle and joins with the medial and intermediate cutaneous nerves of the thigh above the knee joint, and on the lateral side of the patella, it joins with the lateral cutaneous nerve of the thigh, and below the patella, it joins with the other branches of the saphenous nerve and thus forms the *patellar plexus.* It is through this plexus that it supplies the skin in front of the knee joint.
(3) Two terminal branches.

Obturator nerve. It arises from the anterior primary rami of the second, third and the fourth lumbar nerves. At first it lies within the psoas major muscle and then emerges from its medial side to the brim of the pelvis. In the pelvis it at first lies behind the common iliac artery and on the lateral side of the internal iliac artery. Then it runs forwards and laterally on the lateral wall of the pelvis to reach the upper part of the obturator foramen where it is accompanied by the

obturator vessels which lie below it. It then divides into anterior and posterior branches.

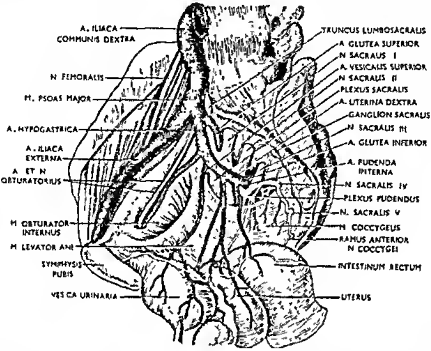


Fig 863 Lateral view of the female pelvis to show the main arteries and nerves. The bladder, rectum and pelvic genital organs are drawn downwards to show their arterial supply. With kind permission from Callander's Surgical Anatomy, 2nd edition, 1939; W. B. Saunder's Company: Philadelphia and London.

The *anterior branch* gives a twig to the hip joint and passes in front of the obturator externus. It then enters the thigh by passing in front of the adductor brevis and lies under cover of the pectineus and adductor longus. At the lower border of the adductor longus muscle it communicates with the posterior division of the medial cutaneous nerve of the thigh and the saphenous nerve to form the subsartorial plexus. It then descends upon the femoral artery to which it is finally distributed. Behind the pectineus it provides muscular branches to gracilis, adductor longus, pectineus and sometimes to the adductor brevis.

The *posterior branch* passes through the fibres of the obturator externus muscle and then enters the thigh behind the adductor brevis and in front of the adductor magnus muscle. It then descends on the latter muscle and then either pierces it or passes through the femoral opening and enters the popliteal fossa. It finally ends by piercing the oblique posterior ligament of the knee joint. In the popliteal fossa it lies postero-medial to the artery. In its course it supplies the obturator externus, adductor magnus, and sometimes the adductor brevis.

N.B.—Adductor magnus has double nerve supply. In addition to the obturator nerve (Post-div) it receives a twig from the sciatic nerve.

THE SACRAL PLEXUS OF NERVES

The *sacral plexus of nerves* consists of six nerve roots, namely, part of the anterior primary ramus of the 4th lumbar nerve, the anterior primary ramus of the 5th nerve and the anterior primary rami from the first to the fourth sacral nerves. Like

other spinal nerves, each nerve root receives a grey ramus communication from the sympathetic ganglion which it conducts to the blood vessels, sweat and sebaceous glands in their territory. The sacral and coccygeal plexuses of nerves behave in a different manner from other spinal nerves in that, from second sacral nerves and below, *no white ramus communications* are given off by them to join the sympathetic ganglia but they are distributed to the pelvic viscera through the hypogastric plexus and constitute the *pelvic splanchnic nerves.* The *second, third* and the *fourth* sacral nerve, contain parasympathetic fibres (anti-sympathetic) and constitute the autonomic pelvic splanchnic nerves or the *nervi errigentes.*

Mode of formation. The fifth lumbar nerve joins with the remainder of the fourth lumbar nerve near the pelvic brim to form the *lumbo-sacral nerve trunk.* Each of the upper four sacral nerves divides into anterior and posterior divisions. The anterior primary rami of the upper four sacral nerves unite with the lumbo-sacral nerve trunk in the following ways and form the sacral plexus. (The anterior primary ramus of the fourth sacral nerve divides into upper and lower branches. The upper branch joins in the sacral plexus while the lower branch joins in the coccygeal plexus).

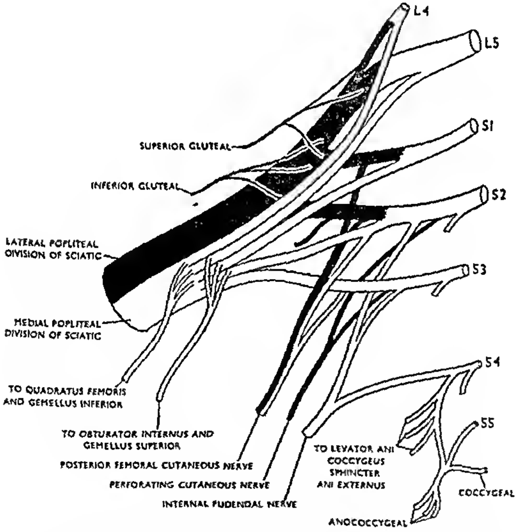


Fig. 864. A schematic drawing of the sacral plexus of nerves and its branches.

The lumbo-sacral nerve trunk unites with the first sacral nerve in front of the sacroiliac joint to form a nerve trunk which unites with the second, third and

Nerve	Numerical root value	Supply	Remarks
(7) Posterior femoral cutaneous nerve	S, 1, 2, 3	Skin of the back of the thigh, skin of the back of the leg up to the middle of the leg, skin of the lower and posterior part of the gluteal region and the skin of the perineum.	..
(8) Sciatic	L. 4, 5 S. 1, 2, 3	Biceps femoris, semimembranosus, semitendinosus and the adductor magnus	..
(9) Pudendal	S. 2, 3, 4	*By perineal branches*— (*a*) Transversus perinei profundus, (*b*) Transversus perinei superficialis, (*c*) Ichiocavernosus, (*d*) Bulbospongiosus, (*e*) Corpus spongiosum penis, (*f*) Skin of the scrotum or labium, (*h*) Mucous membrane of the urethra. *By dorsal nerve of the penis or clitoris*— (a) Corpus cavernosum penis, (*b*) Crus penis or clitoris.	..
[illegible] and perfora- [illegible] branches	S. 2, 3,	Skin of the perineum and the ischiorectal fossa	They enter the perineal and anorectal regions by perforating the sacrotuberous ligament.

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Nerve to the levator ani, coccygeus and the sphincter ani externus. The respective nerve arises from the fourth sacral nerve and then enters the respective muscle through its pelvic surface.

The pelvic splanchnic nerves (nervi errigentes). They arise from the second, third and the fourth sacral nerves. By the side of the rectum they unite with the corresponding nerves of the opposite side and also with the hypogastric nerve from the sympathetics to form a plexus, the *hypogastric plexus* which now contains both sympathetic and parasympathetic fibres. Then they are distributed to the wall of the internal iliac artery and through its branches they supply the rectum, bladder, prostate and seminal vesicles (in the male), and the uterus and the ovary (in case of female). Some of its branches pierce the urogenital diaphragm and the bulb of the penis, others pass below the symphysis pubis, accompany the dorsal vein of the penis and join with the dorsal nerve of the penis and are distributed to the cavernous tissue of the penis in male. In case of females, they supply the erectile tissue of the clitoris.

Functionally the hypogastric nerve (sympathetic nerve) and the nervi errigentes (para-sympathetic nerve) are antagonistic to each other. The nervi errigentes causes relaxation of the internal sphincters of the bladder and the anal canal and at the same time causes contraction of their muscle wall and thus helps in the expulsion of their content (nerve of evacuation). The hypogastric has the contrary effect. They cause contractions of the sphincters and relaxation of the walls of the bladder and rectum. Both nerves carry sensory fibres, the pelvic splanchnic nerves carrying probably the touch, heat and ordinary pain sensations while the hypogastric nerves carrying pain fibres of the nature of spasmodic contraction. The pelvic splanchnic nerves also send ascending branches along the left common iliac artery which join the sympathetics on the inferior mesenteric artery and are distributed through its branches to the left half of the transverse colon, the descending and the pelvic colons. The hypogastric nerves cause the prostate and the seminal vesicles to contract and empty their content. The pelvic splanchnic nerve supplies vasodilator fibres to the arteries supplying the cavernous tissue of the penis and thus cause erection of the penis (or clitoris). Because it causes erection, the original term 'nervus errigens' came into being.

Summary of distribution of the branches of the sacral plexus

Nerve	Numerical root value	Supply	Remarks
(1) Nerve to the piriformis	S. 1, 2	Piriformis muscle	Enters the anterior surface of the muscle.
(2) Nerve to the levator ani, coccygeus and sphincter ani externus	S. 4	Respective muscle	Enters the pelvic surface of individual muscle.
(3) Superior gluteal nerve	L. 4, 5 S. 1	Gluteus minimus, gluteus medius and tensor fascia lata	It emerges out of the pelvic cavity through the greater sciatic notch and passes *above the piriformis.*
(4) Inferior gluteal nerve	L. 5 S. 1, 2	Gluteus maximus	It passes below the piriformis muscle as it comes out through the greater sciatic notch.
(5) Nerve to the quadratus femoris	L. 4, 5 S. 1	Quadratus femoris, gemellus inferior and the capsule of the hip joint.	..
(6) Nerve to the obturator internus	L. 4, 5 S. 1	Obturator internus and gemellus superior	..

Nerve	Numerical root value	Supply	Remarks
(7) Posterior femoral cutaneous nerve	S, 1, 2, 3	Skin of the back of the thigh, skin of the back of the leg up to the middle of the leg, skin of the lower and posterior part of the gluteal region and the skin of the perineum.	..
(8) Sciatic	L. 4, 5 S 1, 2, 3	Biceps femoris, semimembranosus, semitendinosus and the adductor magnus	..
(9) Pudendal	S. 2, 3, 4	*By perineal branches*— (*a*) Transversus perinei profundus, (*b*) Transversus perinei superficialis, (*c*) Ischiocavernosus, (*d*) Bulbospongiosus, (*e*) Corpus spongiosum penis, (*f*) Skin of the scrotum or labium, (*h*) Mucous membrane of the urethra. *By dorsal nerve of the penis or clitoris*— (*a*) Corpus cavernosum penis, (*b*) Crus penis or clitoris.	..
(10) Perineal and perforating cutaneous branches	S. 2, 3,	Skin of the perineum and the ischiorectal fossa	They enter the perineal and anorectal regions by perforating the sacrotuberous ligament.
(11) Nervus errigentes	S 2, 3, 4	Provides para-sympathetic fibres to the pelvic viscera, descending and pelvic colons and the arteries of the penis or clitoris.	77

Summary of nerve plexuses in the abdomen

Plexus		Anterior primary rami of			
		Thoracic	Lumbar	Sacral	Coccygeal
Lumbar plexus	..	12	1, 2, 3, 4	—	—
Sacral plexus	..	—	4, 5	1, 2, 3, 4	—
Coccygeal plexus	..	—	—	4, 5	1

Pudendal nerve. It is one of the terminal branches of the sacral plexus and derives its fibres from the second, third and the fourth sacral nerves. It descends between the piriformis and the coccygeus and passes to the gluteal region through the greater sciatic foramen below the piriformis muscle. In the gluteal region it crosses the back of the ischial spine and lies medial to the internal pudendal vessels.

then re-enters the pelvic cavity through the lesser sciatic foramen and then lies the lateral wall of the ischiorectal fossa where it gives out the inferior rectal anch and then divides into perineal and the dorsal nerve of the penis.

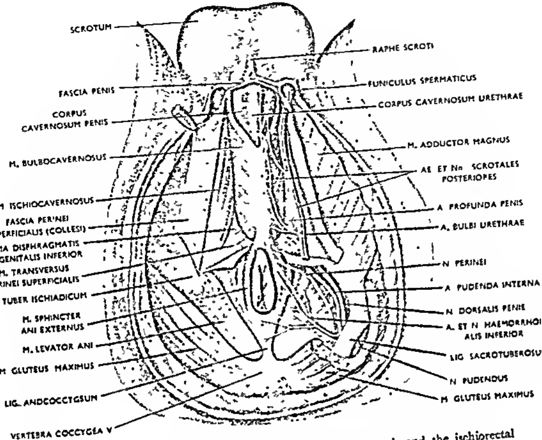


Fig. 865. The male perineum. Both the superficial perineal pouch and the ischiorectal fossae have been exposed Note the distribution of the pudendal nerve. With kind permission from Callanders Surgical Anatomy, 2nd edition, 1939, W. B. Saundar's Company: Philadelphia and London.

The perineal nerve. It is the larger terminal branch of the pudendal nerve. t accompanies the perineal artery and pierces the posterior part of the perineal nembrane and divides into muscular and scrotal or labial branches. The muscular branches supply the sphincter urethrae, transversus perinei profundus and superficialis, bulbocavernosus and the ischiocavernosus. The nerve to the bulbocavernosus provides a twig to the bulb of the urethra (nerve to the urethral bulb) which it pierces and supplies the corpus spongiosus penis and the mucous membrane of the urethra.

The scrotal or the *labial branches* are two in number—lateral and medial and they supply the skin of the scrotum or the labium as the case may be, and end by communicating with the perineal branches of the posterior cutaneous nerve of the thigh.

The dorsal nerve of the penis. It is the smaller terminal branch of the pudendal nerve and lies in the deep pouch of the perineum in close relation to the internal pudendal artery and then pierces the anterior part of the perineal membrane. It then runs with the dorsal artery of the penis and supplies the corpus cavernosum penis and finally ends in the glans penis. In the female it is called the dorsal nerve of the clitoris which supplies the clitoris.

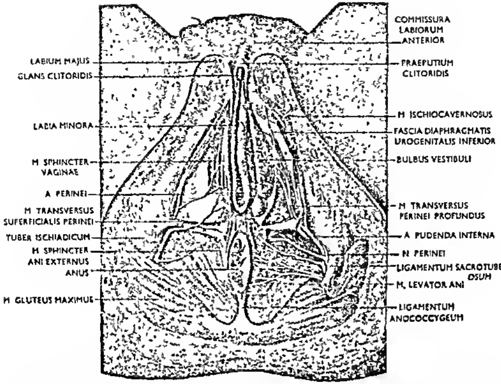


Fig. 866. The female perineum. Both the superficial perineal pouch and the ischiorectal fossae have been exposed. Note the distribution of the pudendal nerve. With kind permission from Callanders Surgical Anatomy, 2nd edition, 1939, W. B. Saunder's Company: Philadelphia and London.

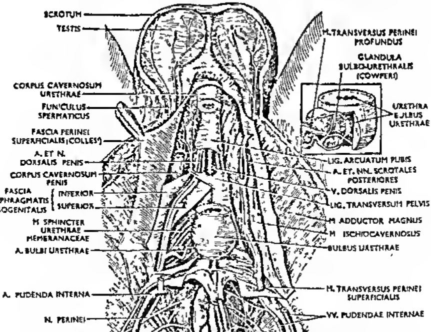


Fig. 867. The pouches of the perineum and the ischiorectal fossae. Note the distribution of the pudendal nerve. With kind permission from Callanders Surgical Anatomy, 2nd edition, 1939, W. B. Saunder's Company. Philadelphia and London.

Superior gluteal nerve. It arises from the dorsal branches of the anterior primary rami of the fourth and fifth lumbar nerves and from the first sacral nerve. It enters the gluteal region through the greater sciatic foramen above the piriformis muscle. It accompanies the superior gluteal artery and soon divides into superior and inferior branches.

The *superior branch* accompanies the upper branch of the deep divisioo of the superior gluteal artery and then ends by supplying the gluteus minimus muscle. The *inferior branch* accompanies the lower branch of the deep division of the superior gluteal artery and supplies the gluteus minimus, gluteus medius and the tensor fasciae latae muscles.

Inferior gluteal nerve. It passes from the pelvis through the greater sciatic foramen below the piriformis muscle. Its fibres are derived from the dorsal branches of the anterior primary rami of the fifth lumbar and first and second sacral nerves. It soon divides into branches which enter the deep surface of the gluteus maximus muscle.

Nerve to the quadratus femoris. It derives its fibres from the ventral branches of the anterior primary rami of the fourth and fifth lumbar and the first sacral nerves. It enters the gluteal region through greater sciatic foramen below the piriformis muscle. At first it lies behind the sciatic nerve and then passes deep to the common tendon of obturator internus and the gemelli. Then it supplies a twig to the gemellus inferior and finally enters into the anterior surface of the quadratus femoris muscle. It also provides a twig to the articular capsule of the hip joint.

Nerve to the obturator internns. It derives its fibres from the ventral branches of the fifth lumbar nerve and the first and second sacral nerves.

It comes out to the gluteal region through the greater sciatic foramen below the piriformis muscle and then crosses the back of the ischial spine where it lies on the lateral side of the internal pudendal vessels. In this situation it provides a twig to the gemellus superior muscle and then re-enters the pelvis through the lesser sciatic foramen and finally enters into the pelvic surface of the obturator internus.

Posterior cutaneous nerve of the thigh (Posterior femoral cutaneous nerve). It derives its fibres from the dorsal branches of the anterior primary rami of the first, and second sacral and from the ventral branches of the anterior primary rami of the second and third sacral nerves. It emerges to the gluteal region through the greater sciatic foramen below the piriformis muscle. In the gluteal region it lies under cover of the gluteus maximus and descends downwards with the inferior gluteal artery on the medial side of the sciatic nerve. Then it descends vertically downwards through the back of the thigh, and opposite the back of the knee joint, it pierces the deep fascia and becomes cutaneous and descends downwards along with the short saphenous vein; opposite the middle of the leg it ends by communicating with the sural nerve. In its course it gives out collateral branches which supply the skin of the back of the thigh and the skin of the back of the leg as far as the middle of it.

It also supplies the skin covering the lower and lateral part of the gluteus maximus muscle by its gluteal branches. By its perineal branches it supplies the upper and medial part of the thigh, scrotum or labium majus and ends by communicating with scrotal and perineal nerves.

Perineal and perforating cutaneous nerves. They arise from the second, third and the fourth sacral nerves; they pierce the structures attached to the lateral side of the coccyx and finally are distributed to the skin covering the ischiorectal fossa and the perineum.

Sciatic nerve. It is the larger terminal branch of the sacral plexus and is the largest nerve in the body. At its origin it is wide as much as 2 cm. It enters the gluteal region through the greater sciatic notch below the piriformis muscle

and lies in the interval between the greater trochanter of the femur and the ischial tuberosity. It then descends on the back of the thigh and finally divides into common peroneal (lateral popliteal) and tibial (medial popliteal) nerves opposite the junction of the middle with the lower-third of the thigh.

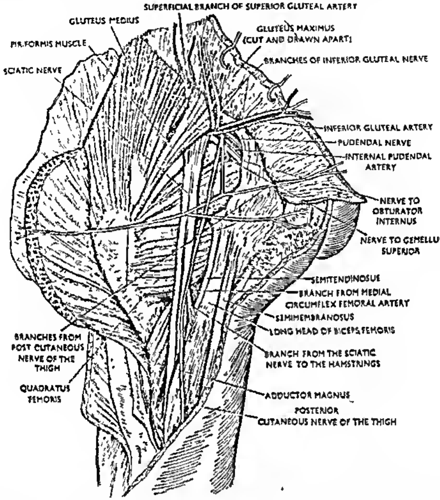


Fig. 868. The structures under the gluteus maximus. Note the position of the sciatic and other nerves. From the dissection hall, N. R. Sircar Medical College, Cal.; with kind permission from the Prof. of Anatomy.

In the gluteal region it is covered by the gluteus maximus muscle and lies upon the posterior surface of the ischium, the nerve to the quadratus femoris intervening. It then lies successively upon the common tendon of obturator internus and the gemelli and the quadratus femoris muscle.

It is separated from the obturator externus and the capsule of the hip joint by the quadratus femoris muscle. On its medial side there lies the posterior cutaneous nerve of the thigh and the inferior gluteal vessels. In the thigh it lies upon the adductor magnus muscle and is obliquely crossed by the long head of the biceps femoris muscle.

Branches:

(1) Articular to the hip joint.
(2) Muscular to hamstrings (Biceps femoris, semimembranosus and semitendinosus) and adductor magnus.
(3) Terminal, common peroneal and tibial nerves.

tibialis posterior, flexor digitorum longus and the flexor hallucis longus. The nerve to the flexor hallucis longus runs in company with the peroneal vessels.

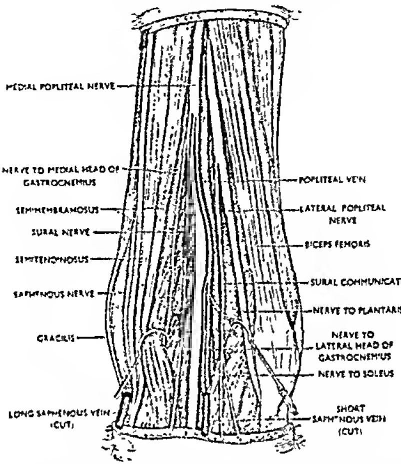


Fig. 870. The dissection of the popliteal fossa. Note the position of the common peroneal and tibial nerves. From the dissection hall, N. R. Sircar Medical College, Cal.; with kind permission from the Prof. of Anatomy.

The nerve to the popliteus. After its origin from the tibial (medial popliteal) *nerve in between the two heads of the gastrocnemius* it *crosses the popliteal* vessels and reaches the lower border of the popliteus muscle. Then it winds round its lower border and ends into its deep surface. It also provides a small muscular branch to the tibialis posterior muscle, an articular branch to the superior tibio-fibular joint, an interosseous branch which runs downwards in close relation to the fibula and ends by supplying the inferior tibio-fibular joint, and a medullary branch to the tibia.

The nerve to the plantaris. It is the first lateral and the highest branch of the tibial (medial popliteal) nerve and arises from it above the knee joint and ends by entering into the plantaris muscle.

The nerve to the lateral head of the gastrocnemius. It lies below the nerve to the plantaris and ends by entering into the lateral head of the gastrocnemius.

Nerve to the soleus. It arises from the tibial (medial popliteal) nerve opposite the back of the knee joint and immediately above the nerve crosses the popliteal artery. It descends on the lateral side of the popliteal artery for a short distance and then enters into the soleus muscle.

Nerve to the medial head of the gastrocnemius. It arises from its medial above the knee joint and ends by entering into the medial head of the gas-nemius.

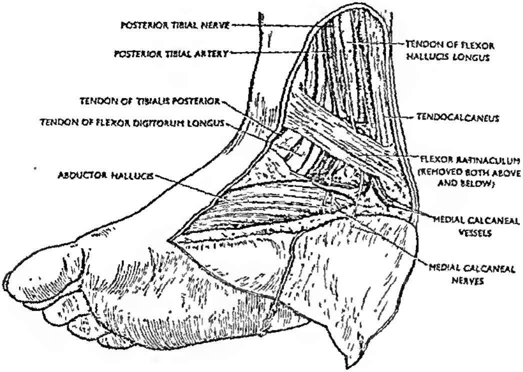


Fig. 871. The medial aspect of the right ankle and the adjoining areas to show the structures under the flexor retinaculum which has been removed both above and below. Note the distribution of the medial calcaneal vessels and nerves From the dissection hall, N. R. Sircar Medical College, Cal.; with kind permission from the Prof. of Anatomy.

(3) **Sural.** It is a cutaneous branch from the tibial (medial popliteal) nerve which descends in between the two heads of the gastrocnemius and pierces the deep fascia opposite the middle of the leg. It then lies on the lateral side of the tendo-calcaneus and finally goes to the lateral side of the foot and supplies the lateral margin of the foot and the lateral side of the little toe. On the back of the leg it is joined by the sural communicating branch from the common peroneal (lateral popliteal) nerve and lies in close relation to the short saphenous vein. On the back of the leg it also communicates with the posterior cutaneous nerve of the thigh; on the lateral side of the foot it communicates with the lateral branch of the superficial peroneal (musculocutaneous) nerve.

(4) *Cutaneous.* They are the medial calcaneal nerves which together with :al branches of the posterior tibial artery perforate the flexor retinaculum · the skin of the heel and the medial side of the sole of the foot.

erminal. They are the medial and lateral plantar nerves (see sole of

nedial plantar nerve. It is the medial terminal branch of the (posterior) e and begins under cover of the flexor retinaculum. It then passes deep uctor hallucis in company with the medial plantar vessels to reach the :tween the abductor hallucis and the flexor digitorum brevis where it o plantar digital nerves. It lies on the lateral side of the medial plantar

...... and distribution:

(1) *Cutaneous.* They pierce the plantar aponeurosis in the interval between the abductor hallucis and the flexor digitorum brevis and supply the skin of the medial part of the sole of the foot.

(2) *Articular.* They supply the articulations of the tarsus and metatarsus.

(3) *Digital nerve of the great toe.* It supplies the medial side of the great toe and also provides a small twig to flexor hallucis brevis muscle.

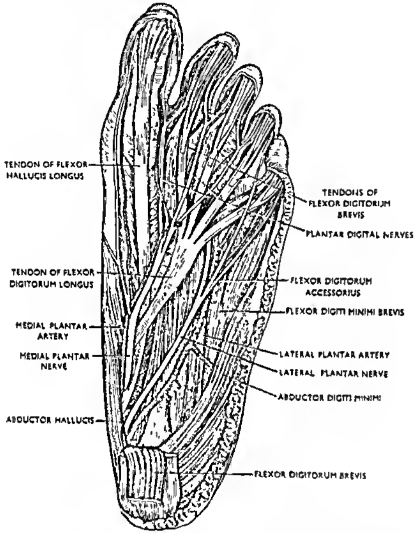


Fig. 872. The sole of the left foot to show the structures of the second layer. Note the distribution of the medial and lateral plantar nerves. From the dissection hall, N. R. Sircar Medical College, Cal; with kind permission from the Prof. of Anatomy.

(4) *Plantar digital nerves.* They are three in number. The first plantar digital nerve supplies a twig of the first lumbrical muscle and divides into two branches which supply the contiguous sides of the great and the second toes. The second supplies the second and the third toes, and the third receives a communicating branch from the lateral plantar nerve and then supplies the sides of the third and the fourth toes.

Each digital nerve after reaching the digits gives out cutaneous, articular and the dorsal branches. The cutaneous branches supply the skin as far as the ball of each toe, the articular branches supply the interphalangeal joints. The dorsal branch is given out opposite the distal phalanx and it goes upwards and ends by supplying the nail bed and structures around it.

The lateral plantar nerve. It is the smaller terminal branch of the (posterior) tibial nerve. It supplies the lateral side of the little toe and the contiguous sides

he little and the fourth toes and it also supplies the abductor digiti minimi, flexor digiti minimi brevis, the flexor digitorum accessorius, the adductor hallucis, second, third and the fourth lumbricales and all the interossei muscles.

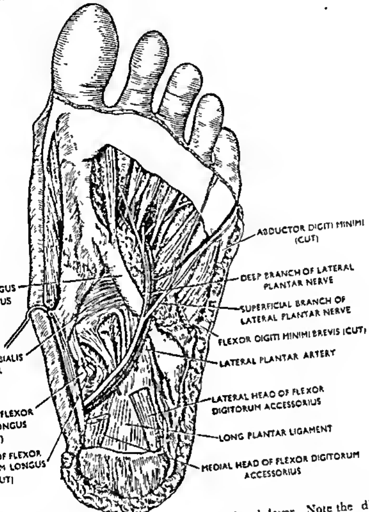


Fig. 873. The sole of the left foot to show the structures of the fourth layer. Note the distribution of the deep division of the lateral plantar nerve. From the dissection hall, N. R Sircar Medical College, Cal.; with kind permission from the Prof of Anatomy.

Accompanying the lateral plantar artery, which lies on its lateral side, it enters the sole of the foot behind the abductor hallucis muscle and then reaches the lateral side of the sole of the foot by passing between the flexor digitorum brevis and the flexor digitorum accessorius muscle. Reaching the interval between the flexor digitorum accessorius and the abductor digiti minimi it gives out a branch which supplies the flexor digitorum accessorius and the abductor digiti minimi and then divides into superficial and the deep branches.

The *superficial branch* divides into lateral and medial branches. The lateral branch supplies the lateral side of the little toe and provides muscular branches which supply the flexor digiti minimi brevis and the third plantar and the fourth dorsal interossei muscles (*i.e.*, the interosseous muscles of the fourth intermetatarsal space). The medial branch supplies the contiguous sides of the fourth and the little toes and communicates with the third plantar digital branch of the medial plantar nerve.

The *deep branch* accompanying the lateral plantar artery passes deep to the flexor tendons and the adductor hallucis muscle. It then divides into branches which supply the adductor hallucis, the second, third and the fourth lumbricales,

the first, second and the third dorsal interrossei and the first and the second plantar interossei muscles, *i.e.*, it supplies all the interossei muscles except those which occupy the fourth intermetatarsal space.

The common peroneal (lateral popliteal) nerve. It begins opposite the junction of the middle with the lower-third of the thigh as one of the terminal branches of the sciatic nerve. Its fibres are derived from the dorsal division of the anterior primary rami of the 4th and 5th lumbar and the 1st and 2nd sacral nerves. It descends downwards along the lateral side of the popliteal fossa lying deep to the tendon of the biceps femoris muscle. In the lower part of the popliteal fossa it intervenes between the tendon of the biceps femoris and the lateral head of the gastrocnemius muscle. Then it winds round the lateral side of the neck of the fibula under cover of the peroneus longus muscle and finally it divides into superficial peroneal (musculocutaneous) and deep peroneal (anterior tibial) nerves.

Branches:

(1) *Articular.* Three in number—superior lateral genicular, inferior lateral genicular and the anterior tibial recurrent. They accompany the corresponding arteries and end by supplying the knee joint.

(2) *Cutaneous.* Two in number—lateral cutaneous nerve of the calf of the leg and the sural communicating. The lateral cutaneous branch supplies the anterior, posterior and the lateral aspects of the upper part of the leg. The sural communicating joins with the sural nerve opposite the middle of the calf of the leg.

(3) *Terminal.* Deep peroneal (Anterior tibial) and the superficial peroneal (musculocutaneous).

The deep peroneal (anterior tibial) nerve. It is the larger terminal branch of the common peroneal nerve and supplies the muscles of anterior crural region (Tibialis anterior, extensor digitorum longus, extensor hallucis longus and the peroneus tertius), the first and the second dorsal interossei, the extensor digitorum brevis, all the tarsal articulations, the metatarsophalangeal joints of the first, second, third and the fourth toes and also supplies the contiguous sides of the great and the second toes.

At its origin it lies between the neck of the fibula and the peroneus longus muscle and then passes downwards and forwards behind the extensor digitorum longus and reaches the front of the interosseous membrane. It then comes in close relation to the anterior tibial vessels. Accompanying the anterior tibial vessels it descends downwards to the front of the ankle joint where it lies beneath the superior extensor retinaculum and in this situation divides into medial and lateral branches. At first it lies on the lateral side of the artery, then in front of it and in the lower part of the leg and in front of the ankle joint it again goes to its lateral side.

The medial branch of the deep peroneal (anterior tibial) nerve runs forwards on the dorsum of the foot and lies on the lateral side of the arteria dorsalis pedis. It lies in the first intermetatarsal space and provides a communicating branch, an interosseous and two terminal dorsal digital nerves.

The communicating branch communicates with the medial branch of the superficial peroneal (musculocutaneous) nerve in the same space. The interosseous branch provides a twig to the first dorsal interosseous muscle and supplies articular filaments for the first metatarsophalangeal joint. The two dorsal digital nerves supply the contiguous sides of the great and the second toes.

The *lateral branch* passes laterally across the tarsal bones lying deep to the extensor digitorum brevis muscle and then forms pseudogangliform enlargement like that of the posterior interosseous nerve at the wrist from which it gives out three interosseous branches. It provides a muscular branch which supplies the extensor digitorum brevis muscle. The interosseous branches supply all the tarsal joints and the metatarsophalangeal joints of the second, third and the fourth toes. The first interosseous branch supplies a twig to the second dorsal interosseous muscle.

The superficial peroneal nerve (musculocutaneous nerve of the leg). s the smaller terminal branch of the common peroneal (lateral popliteal) nerve. first supplies muscles and then becomes cutaneous and hence it is called musculocutaneous. It supplies the peroneus longus et brevis muscle, the skin of the lower rt of the front of the g, the skin of the dorsum the foot, the medial le of the great toe, the djacent sides of the cond and the third toes, he third and the fourth nd the fourth and the ifth toes.

At its origin the superficial peroneal (musculocutaneous) nerve lies between the neck of the fibula and the peroneus longus muscle, then it descends through the fibres of the peroneus brevis and lies between the peronei and the extensor digitorum longus muscles and finally reaching the lower one-third of the leg it pierces the deep fascia and then divides into medial and lateral branches. In its course through the peronei it provides muscular branches to the same muscles.

In its course through the lower part of the leg it provides cutaneous branches which supply the skin of the front of the lower part of the leg.

The *medial branch* passes the front of the ankle joint and divides into two dorsal digital nerves—one supplies the medial side of the great toe and communicates with the saphenous nerve and the other communicates with the medial branch of the anterior tibial nerve and then supplies the contiguous sides of the second and the third toes.

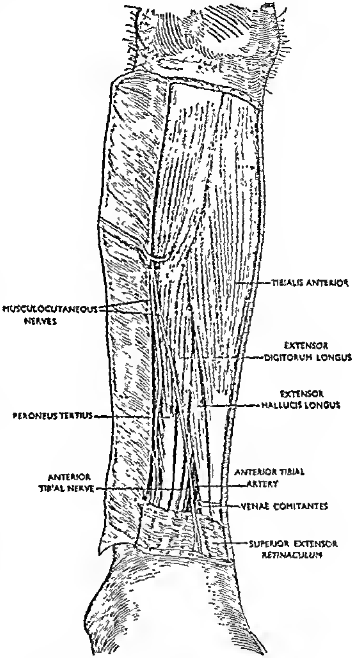


Fig. 874. The right tibio-fibular region to show the structures in the extensor compartment. Note the superficial and the deep peroneal nerves. From the dissection hall, N. R. Sircar Medical College, Cal.; with kind permision from the Prof. of Anatomy.

The *lateral branch* passes to the lateral side of the dorsum of the foot and then divides into two dorsal digital nerves. One supplies the adjacent sides of the third and the fourth toes and the other communicates with the sural nerve on the lateral side of the foot and then supplies the contiguous sides of the fourth and the fifth toes.

The medial and the lateral branches of the superficial peroneal nerve provide cutaneous filaments which supply the skin on the dorsum of the foot.

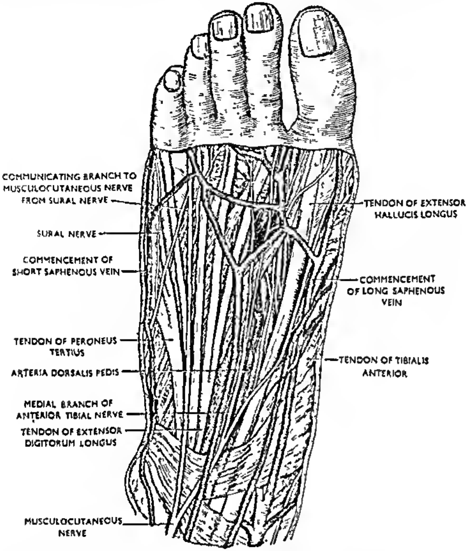


Fig 875. The dorsum of the right foot. Note the distribution of the cutaneous nerves. From the dissection hall, N R. Sircar Medical College, Cal.; with kind permission from the Prof. of Anatomy

Neurological value of the muscles of the leg and the foot:

(1) *Muscles supplied by the deep peroneal (anterior tibial) nerve*—(L. 4, 5 and S. 1).
- (*a*) Tibialis anterior.
- (*b*) Extensor hallucis longus.
- (*c*) Extensor digitorum longus.
- (*d*) Peroneus tertius.
- (*e*) Extensor digitorum brevis.
- (*f*) First and second dorsal interossei muscles.

(2) *Muscles supplied by the crural or lower part of the tibial nerve*—
- (*a*) Flexor digitorum longus (L. 5 and S. 1).
- (*b*) Flexor hallucis longus (L. 5 and S. 1 and 2).
- (*c*) Tibialis posterior (L. 5 and S. 1).

(3) *Muscles supplied by the (superficial peroneal) musculocutaneous nerve of the leg—*
- (*a*) Peroneus longus (L. 4, 5 and S. 1).
- (*b*) Peroneus brevis (L. 4, 5 and S. 1).

(4) *Muscles supplied by the medial plantar nerve—*
- (*a*) Abductor hallucis (L. 5 and S. 1).
- (*b*) Flexor digitorum brevis (L. 5 and S. 1, 2, 3).
- (*c*) Flexor hallucis brevis (L. 5 and S. 1).
- (*d*) First lumbrical (L. 5 and S. 1).

(5) *Muscles supplied by the lateral plantar nerve—*
- (*a*) Abductor digiti minimi (S. 1, 2).
- (*b*) Flexor digitorum accessorius (S. 1).
- (*c*) Flexor digiti minimi brevis (S. 1, 2).
- (*d*) All the interossei muscles (S. 1, 2).
- (*e*) Second, third and the fourth lumbricales (S. 1, 2).
- (*f*) Adductor hallucis (S. 1, 2).

THE AUTONOMIC NERVOUS SYSTEM

The autonomic nervous system is an integral part of the central nervous system vhose action is automatic without having any voluntary control. It has wide field)f distribution and like the somatic system it also possesses efferent and afferent fibres ınd centres in the cortex and in the hypothalamus. But it differs from the somatic ıerves in that its fibres have cell stations outside the central nervous system in some)eripheral ganglia before they reach their destination.

The autonomic nervous system consists of a central portion and a peripheral)ortion. The central portion has a cortical and a hypothalamic representations. The peripheral portion consists of the sympathetic and the parasympathetic systems. Each of these systems again consists of efferent and afferent paths.

Cortical representation. The premotor area of the brain, area 6, which s confined to the anterior part of the precentral gyrus and the posterior parts of the uperior and middle frontal gyri, is believed to have a cortical representation of the entral antonomic nervous system.

Hypothalamic representation. *The anterior portion of the hypothalamus* epresents the hypothalamic centre for the sympathetic system while its posterior)ortion represents the parasympathetic reflex centre.

Autonomic nervous system
- Central autonomic system
  - Cortical centre
  - Hypothalamic centre
- Peripheral autonomic system
  - Sympathetics
    - Efferent
    - Afferent
  - Parasympathetics
    - Efferent
    - Afferent

THE SYMPATHETIC SYSTEM

The sympathetic system consists of sympathetic nerve trunk associated with ympathetic ganglia, there being as a rule one ganglion for each spinal nerve. But n the cervical region there are only three ganglia, superior, middle and inferior,)robably due to fusion of two or more ganglia into one. The inferior cervical ganglion

is often fused with the first thoracic ganglion to form the *stellate ganglion*, and inferiorly, there is only one coccygeal ganglion.

The sympathetic ganglia are connected with one another by a chain of both medullated and non-medullated fibres and thus an elongated chain of fibres with ganglia is formed on each side of the vertebral column. Each sympathetic ganglion receives a white ramus communicans from the anterior root of the corresponding spinal nerve and sends a grey ramus communicans to the same. This mode of communication only exists in the thoracic and upper lumbar regions (third or fourth lumbar nerves). In the cervical and lower lumbar regions sympathetic ganglia do not receive white ramus communicans from the corresponding spinal nerve but they send out grey ramus communicans as usual. The cervical ganglia receive their white ramus communicans from the first or second thoracic spinal nerve while the lumbar ganglia below the fourth lumbar segment of the spinal cord receive white ramus communicans from the upper lumbar nerves.

Collateral ganglia or prevertebral ganglia. In the abdomen there is a system of collateral or prevertebral ganglia which lie in front of the abdominal aorta in association with the origin of its large ventral branches. They are *coeliac*, and *superior* and *inferior mesenteric* ganglia and *plexuses* and it is through these ganglia that the abdominal organs receive their sympathetic innervation. These ganglia receive their white rami communicans from the thoracic region which emerge from sixth to eleventh thoracic ganglia as the splanchnic nerves and end by arborization around these ganglia.

Sympathetic paths. It is known that all sympathetic nerves after their origin from the spinal cord must have a synaptic termination in one or more ganglia before reaching their area of distribution. They arise from the lateral horn of the spinal cord and emerge through the anterior horn along with the anterior root fibres, and then by way of white ramus communicans, they reach the sympathetic ganglion where they end by synaptic termination around the cells of the ganglion. Relay fibres arise from the sympathetic ganglion cells which are then distributed to particular parts or organs. The first neuron fibres, that is, the fibres from the lateral horn of the spinal cord to the sympathetic ganglion, are medullated and are called the *preganglionic fibres* whereas the second neuron fibres, that is, the fibres from the sympathetic ganglion up to the area of distribution, are non-medullated and are called the *post-ganglionic fibres*.

Preganglionic fibres before entering into some particular ganglion or ganglia may pass up and down through the sympathetic trunk and may travel through several ganglia uninterrupted before terminating into their particular ganglion or ganglia. The fibres of distribution, that is, the post-ganglionic fibres either accompany the spinal nerve as grey ramus communicans or accompany some blood vessels to reach their destination.

The fibres of grey ramus communicans pass along with spinal nerve and are distributed along with the same nerve. The areas covered by these fibres are the skin of the trunk and limbs, and their fibres are distributed to the arterioles and capillaries (vaso-constrictor), sweat glands(secretory), arrectores pilorum (hair muscle) and the blood vessels of the muscle (vasodilator).

The post-ganglionic fibres that accompany the blood vessels in the neck are mostly distributed in the structures of the head and neck.

Regional distribution. **Upper limb.** The preganglionic fibres for the upper-limb arise in the upper thoracic segments of the spinal cord and end by synapses around the cells of the stellate ganglion and middle cervical ganglion from where post-ganglionic fibres of distribution arise.

Lower limb. Preganglionic fibres for the lower limb arise from the lower thoracic and upper lumbar segments of the spinal cord.

Hand and neck. The preganglionic fibres for the head and neck arise from the first and second thoracic spinal nerves and ascending along the sympathetic trunk

they end in the superior cervical ganglion from where post-ganglionic fibres arise and are distributed along with the blood vessels as follows:

(*a*) The fibres to the skin supply the arrectores pilorum, sweat glands and the smaller blood vessels.

(*b*) Salivary glands and lacrimal and buccal glands receive secretory and vaso-constrictor fibres.

(*c*) The arteries supplying the brain receive vaso-constrictor fibres.

(d) The eye receives motor fibres to the dilator pupillae, orbitalis muscle and Mullers muscles.

Thoracic viscera. The preganglionic fibres for the thoracic organs arise from the second to the fourth thoracic nerves and are relayed in the stellate ganglion and inferior and middle cervical ganglia from where post-ganglionic fibres arise and are distributed mainly to the cardiac and pulmonary plexuses through which they supply the heart and the lungs. The fibres for the heart are cardio-accellatory and dilator to the coronary arteries. The lungs receive broncho-dilator and vaso-constrictor fibres.

Abdominal organs. The preganglionic fibres supplying the abdominal organs are derived from fifth to eleventh thoracic spinal nerves and emerge through the sympathetic trunk uninterruptedly as the splanchnic nerves. The splanchnic nerves form synapses with the different prevertebral ganglia (coeliac, superior and inferior mesenteric and hypogastric) from which postganglionic fibres arise and supply the different organs along the walls of the vessels as follows:

(*a*) *Stomach and intestines* receive vaso-constrictor and inhibitory fibres for their walls and acceleratory or motor fibres for their sphincters.

(*b*) The *liver* is supplied with vaso-constrictor fibres and their stimulation causes discharge of glucose into the blood.

(*c*) *Urinary bladder* also receives inhibitory fibres for its walls but motor or acceleratory fibres for its sphincter.

(*d*) *Gall bladder* is supplied with motor fibres which are derived from the ninth segment of the spinal cord and their stimulation causes contraction of the same.

(*e*) The *spleen* is supplied with motor fibres to its plain muscle and their stimulation causes diminution in size and expulsion of blood from the spleen.

(*f*) The *suprarenal gland* receives sympathetic fibres which are preganglionic and end by synapses around the medulla of the gland. Stimulation of sympathetics discharges adrenalin into the circulation.

(*g*) The *uterus* is only supplied by sympathetic nerves and its fibres are derived from the 10th, 11th, 12th thoracic, 1st lumbar and 3rd and 4th sacral segments of the spinal cord.

THE CRANIAL OR THE CEPHALIC PART OF THE SYMPATHETIC SYSTEM

The **internal carotid nerve,** which is a bundle of post-ganglionic nerve fibres from the superior cervical sympathetic ganglion, ascends upwards from the upper end of the superior cervical sympathetic ganglion along the dorsal aspect of the internal carotid artery and runs into a plexus around the walls of the artery to form the *internal carotid plexus*. Occasionally a gangliform swelling, the *carotid ganglion* may be found in a plexus on the posterior aspect of the internal carotid artery.

The internal carotid plexus of nerves may be divided into lateral and medial branches which lie along the corresponding aspects of the internal carotid artery. The branches from the plexus supply the internal carotid artery, and through its hypophyseal branches, they supply the hypophysis cerebri and through its terminal branches (Middle and arterior cerebral and the ophthalmic branches) to the pia-mater covering of the brain and the eye-ball. The plexus also provides commu-

nicating branches which communicate with the trigeminal, ciliary and pterygopalatine ganglia and with the ophthalmic, oculomotor, trochlear, abducent nerves and with the tympanic branch of the glossopharyngeal nerve.

The branches to the ciliary ganglion constitute its symphatic root and pass through the ganglion uninterruptedly and then run along with the short and long ciliary nerves. Those accompanying the short ciliary nerves are distributed to the blood vessels of the eye-ball while those accompanying the long ciliary nerves supply the dilator pupillae.

The branches which are destined to connect the pterygopalatine ganglion form the *deep petrosal nerve* which pierces through the cartilage that covers the foramen lacerum and then joins with the greater (superficial) petrosal nerve to form the nerve of the pterygoid canal. They pass through pterygoid canal and join the pterygopalatine ganglion (sphenopalatine ganglion).

The branches which join with the tympanic branch of the glossopharyngeal nerve form the superior and the inferior caroticotympanic nerves which pierce through the wall of the carotid canal to gain entrance into the tympanic cavity where they form the tympanic plexus together with the tympanic branch of the glossopharyngeal nerve.

Within the cavernous sinus the branches from the plexus communicate with the oculomotor, trochlear, abducent and with the ophthalmic nerve.

THE NUCHAL OR THE CERVICAL PART OF THE SYMPATHETIC SYSTEM

The cervical part of the sympathetic system consists of the cervical sympathetic trunk and the three ganglia, superior, middle and inferior, associated with it.

Cervical sympathetics. As elsewhere the cervical sympathetics consist of sympathetic ganglia which are three in number and sympathetic nerve trunk connecting the different ganglia to one another. The three ganglia according to their situations are named as superior, middle and inferior; cervical sympathetics send out grey rami communicans to all the cervical spinal nerves but they do not receive any white rami communicans from them. They derive their spinal fibres (preganglionic fibres) from the first and second thoracic spinal nerves which give white rami communicans to the thoracic sympathetic ganglion through which the spinal fibres ascend in the sympathetic trunk to reach the cervical sympathetic ganglia.

The cervical sympathetic trunk lies in the prevertebral fascia and intervenes between the prevertebral muscles behind and the carotid sheath in front. Above it is continued as the cranial sympathetic and below it is continuous with the thoracic sympathetics. Each ganglion gives out communicating branches, visceral branches and vascular branches.

The superior cervical sympathetic ganglion. It is the largest of the three and fusiform in shape and lies opposite the transverse processes of the second and the third cervical vertebrae and intervenes between the longus capitis muscle behind and the internal carotid artery in front. Its *communicating branches* communicate with the first four cervical nerves with grey rami communicans and also with the glossopharyngeal, vagus and the hypoglossal nerves. Its *visceral branches* are the cardiac and pharyngeal nerves and its *vascular branches* are distributed to the walls of the external carotid artery.

The middle cervical sympathetic ganglion. It is the smallest of the three cervical sympathetic ganglia and lies opposite the transverse process of the sixth cervical vertebra either in front of or behind the inferior thyroid artery. It gives out *communicating branches* to the fifth and sixth cervical nerves; its *visceral branches* are the cardiac and thyroid nerves and its *vascular branches* are distributed to the wall of the inferior thyroid artery.

The inferior cervical sympathetic ganglion. It is larger than the middle ganglion but smaller than the superior one and lies in between the neck of the first rib and the transverse process of the seventh cervical vertebra behind the origin of the vertebral artery. It gives out communicating branches to the seventh and eighth cervical nerves; its visceral branch is the cardiac nerve and its vascular branches are distributed to the wall of the subclavian artery. The inferior cervical ganglion may be fused with the first or first and second thoracic ganglia constituting what is known as *stellate ganglion.* It lies either in front of the lateral border of the longus cervicis or just lateral to it, and the superior intercostal artery lies immediately lateral to it. If the cervical sympathetic is damaged the following syndrome occurs:

(1) **Horner's syndrome.**
- (*a*) Pin-point pupil (Miosis) due to paralysis of the dilator pupillae.
- (*b*) Drooping of the upper eyelid due to paralysis of the tarsal muscle (Muller's muscle).
- (*c*) Recession of the eye-ball within the orbit (Enophthalmos) due to paralysis of the orbitalis muscle that stretches between the margins of the inferior orbital fissure.

(2) Absence of sweating on the same side of the head and face.

N. B. Some of the twigs from superior cervical sympathetic ganglion also pass to the superior bulb of the internal jugular vein and to the meninges of the posterior cranial fossa. The pharyngeal or the laryngopharyngeal branches run downwards and medially to the side wall of the pharynx where they unite with the pharyngeal branches from the vagus and the glossopharyngeal nerves to form the *pharyngeal plexus.* The carotid body is also supplied by some twigs from this branch.

The vascular branches to the external carotid artery are distributed along with its branches. The plexus of nerves that surrounds the facial artery sends some filaments to the submandibular ganglion and that around the middle meningeal artery sends two communicating twigs, one joins with the otic ganglion and the other, which is also known as the *external petrosal nerve,* joins with the ganglion of the facial nerve.

The middle cervical sympathetic ganglion is connected with the inferior ganglion by two or more slender cords of nerves. One of these cords splits to encircle the vertebral artery and another passes is front of the first part of the subclavian artery medial to the origin of the internal thoracic (mammary) artery and then makes a loop that arches below and behind the artery and this loop is known as the *ansa subclavia.*

THE THORACIC PART OF SYMPATHETIC SYSTEM

The thoracic part of the sympathetic system is continuous above with its cervical part and below with its lumbar part. It consists of the sympathetic ganglia, and the trunk which intervenes between the ganglia. The number of the ganglia usually corresponds to the number of the thoracic spinal nerves but their number may be reduced due to either fusion of the first thoracic ganglion or the first and second ganglia with the inferior cervical sympathetic ganglion. The last two or three ganglia may also coalesce together to give the reduced number of the ganglia.

Each thoracic ganglion sends a grey ramus communicans to the corresponding thoracic spinal nerve and receives a white ramus communicans from the corresponding thoracic spinal nerve. The *two rami communicans are attached to the ganglion in a proximal-distal arrangement and the white ramus communicans is distal to the grey one.*

Relations with the ribs and vertebrae. The first thoracic ganglion and the adjoining portion of the sympathetic trunk lie in front of the neck of the first rib and lies under cover of the costal pleura. The thoracic ganglia from second to the ninth lie opposite the head of the numerically corresponding rib being covered by the costal pleura while the last three ganglia lie opposite the sides of the bodies of the corresponding vertebrae.

Branches. In addition to the grey ramus communicans which joins with the corresponding thoracic spinal nerve the thoracic sympathetic ganglia provide medial branches as follows:

The medial branches from the upper five ganglia may conveniently be grouped into vascular and visceral branches.

The vascular branches are slender, short twigs which are distributed to the walls of the thoracic aorta where they form a plexus together with the branches from the greater splanchnic nerve.

The visceral branches are pulmonary, cardiac, oesophageal and tracheal. The *pulmonary branches* come from the second, third and the fourth thoracic ganglia and they end by joining with the posterior pulmonary plexus. The *cardiac branches* emerge from the second, third, fourth and the fifth ganglia and they run medially to join the deep part of the cardiac plexus. The filaments to the trachea and the oesophagus are the small twigs that come from the pulmonary and the cardiac branches to these structures.

The medial branches from the sixth to the twelfth thoracic ganglia constitute the three splanchnic nerves such as the greater, the lesser and the lowest splanchnic nerves as follows.

The greater splanchnic nerve. *Origin.* The medial branches from the sixth to the ninth or tenth thoracic ganglia run obliquely downwards and medially under cover of the costal pleura and as they run downwards the upper branch joins with the branch below it and ultimately reaching the lower part of the thoracic cavity they are all united to form a nerve trunk, the greater splanchnic nerve. The component ganglionic branches, as they descend, cross the intercostal vessels and nerves and the bodies of the lower thoracic vertebrae obliquely on both sides and are related medially to the inferior hemiazygos vein and the descending thoracic aorta on the left side and with the azygos vein and the oesophagus on the right side.

Course. The trunk of the greater splanchnic nerve is short and it runs downwards and medially in front of the bodies of the lower thoracic vertebrae and enters into the abdomen by piercing the corresponding crus of the diaphragm.

Termination. In the abdomen it terminates mainly in the coeliac ganglion and partly into the aorticorenal ganglion and into the suprarenal gland. At its termination opposite the body of the eleventh or twelfth thoracic vertebra the nerve may be associated with a ganglion known as the *ganglion splanchnicum.*

Constituent fibres. The greater splanchnic nerve *contains preganglionic medullated fibres* and *visceral afferent fibres.*

Functional components. Functionally the greater splanchnic nerve contains visceromotor or visceral efferent and viscero-sensory or visceral afferent fibres.

Distribution. Post-ganglionic fibres from the coeliac ganglion provide sympathetic autonomic fibres for the liver, spleen, pancreas and the G. I. tract from stomach down to the right $\frac{2}{3}$ of the transverse colon.

The lesser splanchnic nerve is formed by branches from either ninth and tenth, or tenth and eleventh thoracic sympathetic ganglia and enters into the abdomen by piercing through the crus of the diaphragm along with the greater splanchnic nerve and ends in the aorticorenal ganglion.

The lowest splanchnic nerve arises from the twelfth or the last thoracic ganglion and passes beneath the medial arcuate ligament along with the sympathetic trunk to gain the abdominal cavity where it ends in the renal plexus.

THE LUMBAR PART OF THE SYMPATHETICS

There are five lumbar spinal nerves but there are only four ganglia associated with the lumbar part of the sympathetic chain which lies in front of the bodies of the lumbar vertebrae and descends downwards in relation to the medial margin of the psoas major muscle.

Grey and white rami connections. The lumbar sympathetic ganglia provide grey rami communicans to all the lumbar nerves but only the upper two or three ganglia receive white rami communicans from the corresponding lumbar nerves. Thus the lower lumbar nerves do not provide any white rami communicans to the sympathetic ganglia.

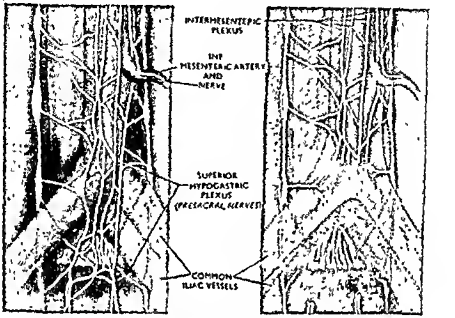


Fig. 876. The lumbar part of the sympathetics and the superior hypogastric plexus. With kind permission from: Callanders Surgical Anatomy, 2nd. ed., 1939, W. B. Saunder's Company, Philadelphia and London

Branches. The lumbar part of the sympathetic system provides visceral and vascular branches.

The *visceral branches* from the lumbar sympathetic ganglia are called the **lumbar splanchnic nerves** and they are four in number, each arising from the corresponding ganglion. The first lumbar splanchnie nerve joins with the coeliac, renal and intermesenteric (aortic) plexuses, the second with the intermesenteric plexus only, the third (which crosses in front of common iliac vessels) with the upper part of the superior hypogastric plexus while the fourth lumbar splanchnic nerve descends downwards deep to the common iliac vessels to terminate in the lower part of the superior hypogastric plexus.

The *vascular branches* from the lumbar ganglia are direct and indirect. Some of the direct branches pass from the ganglia to the intermesenteric plexus, through which, their fibres are distributed, and some others from the lower splanchnic nerves run along the common iliac artery and along it to the external and internal iliac branches. Those accompanying external iliac artery reach as far as the proximal part of the femoral artery. The indirect vascular branches from the lumbar sympathetic ganglia pass to the lumbar nerves by grey rami communicans and then they travel the femoral and the obturator nerve. Through femoral nerve and its branches, the femoral artery and its branches are supplied with vasoconstrictor fibres, and through obturator nerve, the vasoconstrictor fibres are distributed to the obturator vessels.

THE SYMPATETIC SYSTÈM IN THE PELVIC CAVITY

The pelvic part of the sympathetics is continuous above with its lumbar part and the two chains converge below to end into an unpaired, median ganglion, the **ganglion impar** situated in front of the body of the first coccygeal vertebra. The

two chains, one on each side, descend along the front of the bodies of the sacral vertebrae lying medial to the anterior sacral foramina under cover of the parietal peritoneum; the median sacral artery, which descends in front of the sacrum in the median plane, intervenes between the two chains.

Grey and white rami communicans. The sacral sympathetic ganglia provide grey rami communicans to the corresponding sacral nerves but they do not receive any white rami communicans from the sacral nerves.

Branches. Through grey rami communicans postganglionic fibres are distributed to the sacral nerves. These fibres mostly pass through the sciatic nerve and are distributed to the popliteal artery and its branches. Some of the postganglionic fibres also pass along with the superior and inferior gluteal and the pudendal nerves for distribution to their corresponding arteries.

The preganglionic fibres for the upper two or three sacral sympathetic ganglia arise from the lower three thoracic and the upper two or three lumbar segments of the spinal cord (see sympathetic innervation of the lower limb).

THE MAJOR PLEXUSES OF THE SYMPATHETIC SYSTEM

The major plexuses of the sympathetic system are networks of nerves and ganglia from which branches of distribution pass either directly to the organ or organs concerned or through subsidiary plexuses. There are three major plexuses namely the cardiac within the thorax, the coeliac within the abdomen and the hypogastric plexus situated within the pelvic cavity and they have been described briefly in the following pages.

Cardiac plexus. It is an intricate plexus of sympathetic and parasympathetic nerves situated at the base of the heart and consists of two portions, superficial and deep, which communicate freely with each other.

The superficial cardiac plexus. The superficial part of the cardiac plexus is situated in the concavity of the arch of the aorta in between the ligamentum arteriosum and the right pulmonary artery. It is formed by the cardiac branch from the left superior cervical sympathetic ganglion and by the inferior cervical cardiac branch of the left vagus nerve. A small ganglion known as *cardiac ganglion* (Ganglion of Wrisberg) is usually found at the point of union of the two cardiac nerves. This ganglion is supposed to be a parasympathetic ganglion and forms a cell-station for the vagus nerve.

The superficial part of the cardiac plexus sends branches to the deep part of the plexus, to the left anterior pulmonary plexus and to the right coronary plexus.

The *deep part of the cardiac plexus* is situated behind the arch of the aorta in front of the bifurcation of the trachea and above the bifurcation of the pulmonary artery. It is formed by (a) all the cardiac branches from the cervical sympathetics on the right side, that is, the cardiac branches from the right superior, middle and inferior cervical sympathetic ganglia, (b) cervical cardiac branches from the right vagus, (c) the superior cervical cardiac branch of the left vagus, (d) cervical cardiac branches from the left ~~superior~~ and middle cervical ganglia, (e) cardiac branches from the right and left recurrent laryngeal nerves, (f) cardiac branches from the right vagus in the thorax and (g) cardiac branches from the second, third, fourth and the fifth thoracic sympathetic ganglia. Thus it is seen that the deep part of the cardiac plexus is formed by all the cardiac nerves except the superior cervical cardiac branch of the left sympathetic and the inferior cervical cardiac branch of the left vagus nerve, which join in the superficial plexus.

Branches. The *left half* of the deep cardiac plexus sends out (a) branches to the left anteror pulmonary plexus and (b) branches to the left coronary plexus. The *right half* sends out branches to (a) right anterior pulmonary plexus and (b) right coronary plexus.

The *right coronary plexus* receives fibres from both superficial and deep part of ardiac plexus and it accompanies the right coronary artery. Its fibres supply ight atrium and the right ventricle.

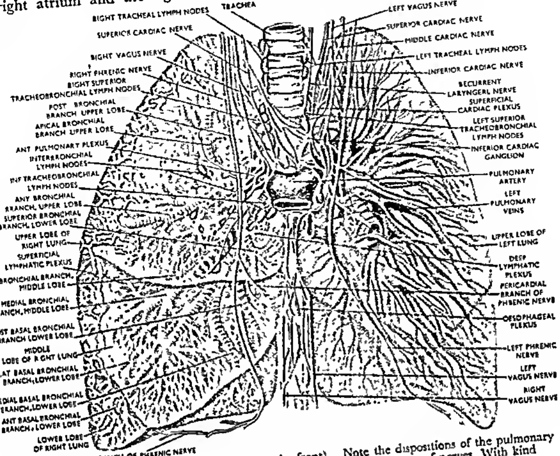


Fig. 877. The anatomy of the lungs (seen from the front). Note the dispositions of the pulmonary veins and the arteries and the cardiac nerves and the oesophageal plexus of nerves. With kind permission from Lederle Laboratories Ltd. Drawn by Mr. Paul Peck.

The *left coronary plexus* accompanies the left coronary artery and it derives its fibres mainly from the left half of the deep cardiac plexus and some from the superficial cardiac plexus. Its fibres supply the left atrium and the left ventricle.

The coeliac plexus and coeliac ganglia. The coeliac plexus is a network nerve fibres intermingled with two large ganglia, the coeliac ganglia, in the abdominal cavity around the coeliac axis from the abdominal aorta.

Situation. It is situated in front of the abdominal aorta, around the origin of the coeliac axis and the superior mesenteric artery from it, and along the medial margin of the crura of the diaphragm and is placed between the two suprarenal glands opposite the bodies of the last thoracic and the upper part of the first lumbar vertebrae.

Relations. It is related in front with the posteroinferior surface of the stomach being separated by the lesser sac of peritoneum, the left edge of the inferior vena cava and the splenic artery. Posteriorly it is related to the front of the upper part of the abdominal aorta and the crura of the diaphragm, the latter separating it from the last thoracic and the upper part of the first lumbar vertebrae; on either side it is related to the suprarenal glands. The coeliac axis and the superior mesenteric artery intervene between the two parts of the plexus.

Each **coeliac ganglion** is an aggregated mass of nerve cells which is split into two parts, upper and lower. The upper part constitutes the coeliac ganglion proper

(10) *Superior mesenteric plexus.* It forms a network around the superior mesenteric artery and derives its fibres from the coeliac plexus of which it is a direct continuation. At the origin of the superior mesenteric artery the plexus may be associated with a ganglion, the *superior mesenteric ganglion.* The branches of distribution follow the branches of the superior mesenteric artery to the organs supplied by them.

(11) *Inferior mesenteric plexus.* It follows the inferior mesenteric artery and derives its fibres from the aortic plexus and from the second and the third lumbar splanchnic nerves. It is distributed along with the branches of the inferior mesenteric artery.

The superior hypogastric plexus. *Formation.* It is, predominently, a plexus of sympathetic nerves and is formed by the continuation of the fibres from the aortic plexus and by the second, third and the fourth lumbar splanchnic nerves. It may contain some parasympathetic fibres from the pelvic splanchnic nerves which ascend through the inferior hypogastric plexus into it. Superiorly it is continuous with the aortic plexus whereas inferiorly it divides into two hypogastric nerves, right and left, which are continuous with the inferior hypogastric plexus. This plexus is often referred to as the *presacral nerve*, particularly by the surgeons.

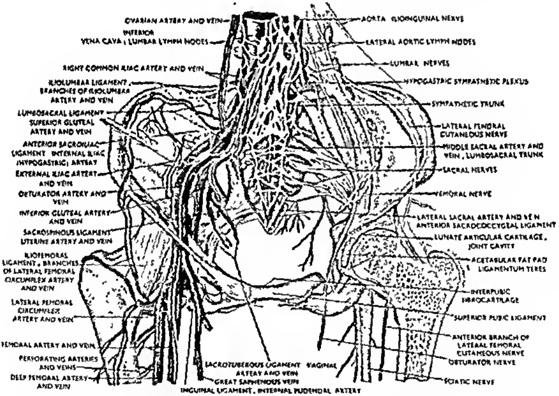


Fig. 878. Anatomy of the pelvis and hip joint. Note the disposition of the external and internal iliac arteries and the sacral and the hypogastic plexus of nerves. With kind permission from Lederle Laboratories Ltd. Drawn by Mr. Paul Peck.

Situation. It is situated in front of the bifurcation of the abdominal aorta, median sacral vessels and the left common iliac vein under cover of the parietal peritoneum and opposite the body of fifth lumbar vertebra and the sacral promontory.

Branches of distribution. It provides branches to the ureter and to the common iliac arteries and also contributes to the formation of the testicular or ovarian plexus and divides into right and left hypogastric nerves inferiorly.

The *hypogastric nerves* are two in number, right and left, which begin as a continuation from the lower end of the superior hypogastric plexus and lies under cover of the parietal peritoneum. Each nerve, which may be split into two or more

filaments being cross-connected to each other, descends downwards in the pelvic cavity on the medial aspect of the internal iliac artery and its branches and then reaches the sides of the rectum, urinary bladder, prostate and the seminal vesicle, in the male, and by the side of the rectum, cervix uteri and the base of the broad ligament and urinary bladder, in the female, where it ends by joining with the inferior hypogastric or pelvic plexus.

Branches. It provides branches to the ureter and to the testicular or ovarian plexus. It is finally distributed in the inferior hypogastric plexus.

Inferior hypogastric or pelvic plexus. It is a mixed plexus of sympathetic and parasympathetic fibres. It's sympathetic fibres are derived from the hypogastric nerves and by the branches from the sacral part of the sympathetics.

The preganglionic fibres are from the tenth, eleventh and twelfth thoracic segments and the first and the second lumbar segments of spinal cord. The postganglionic neurons may be in the ganglia of the lumbar and sacral part of the sympathetics, and aortic and hypogastric plexuses.

The parasympathetic fibres of the plexus are derived from the pelvic splanchnic nerves which arise from the second, the third and the fourth sacral segments of the spinal cord (preganglionic).

Situation. In the male. It is situated by the sides of the rectum, prostate, seminal vesicle and the base of the urinary bladder.

In the female. It is situated by the sides of the rectum, base of the broad ligament, supravaginal part of the cervix uteri and the fornix of the vagina.

Branches of distribution. The branches from the plexus either pass directly to the different pelvic viscera or they are distributed along with the branches from the internal iliac artery. Subsidiary plexuses of distribution, in the male, are middle rectal, vesical and prostatic plexuses, and in the female, are middle rectal, uterovaginal and vaginal plexuses.

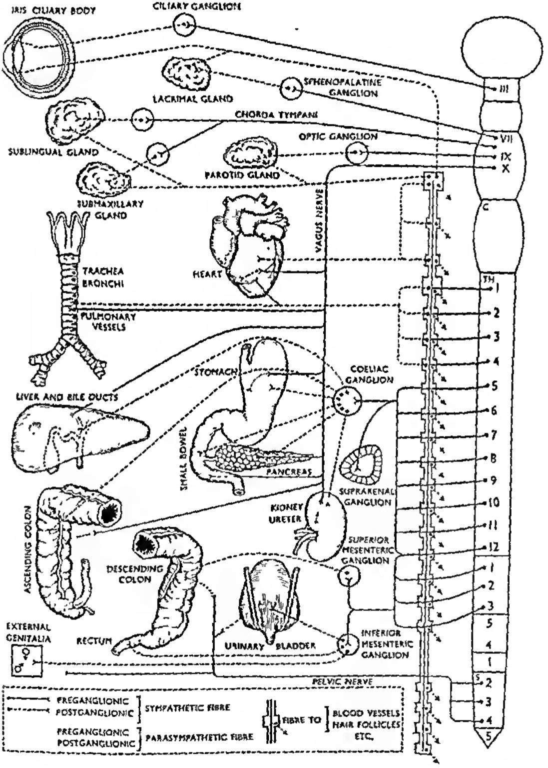
THE PARASYMPATHETIC SYSTEM

The parasympathetic autonomic system consists of mid-brain, bulbar and sacral portions. Parasympathetic paths also consist of preganglionic and postganglionic fibres but here the preganglionic fibres form synapses with ganglia placed on the viscus itself which they supply or in some peripherally disposed ganglia.

Mid-brain outflow. The parasympathetic fibres from the mid-brain arise from the oculomotor nerve nuclei and pass along the oculomotor nerve as preganglionic fibres and form synapses with the ciliary ganglion from where postganglionic fibres arise which supply the sphincter pupillae and the ciliary muscle.

Bulbar outflow. The parasympathetic fibres arising from the medulla oblongata pass along the fibres of the seventh, ninth and tenth cranial nerves. Some of the preganglionic fibres that accompany the facial nerve leave it through a branch which joins the lesser (superficial) petrosal nerve. The lesser (superficial) petrosal nerve joins the otic ganglion through which the preganglionic fibres pass uninterruptedly to join the chorda tympani nerve and from the latter they pass to the submandibular ganglion where they form synapses. Postganglionic fibres from the latter supply secretomotor and vasodilator fibres to the submandibular and sublingual salivary glands. The other preganglionic fibres accompanying the facial pass through the greater (superficial) petrosal nerve and end by synapses in the pterygopalatine (sphenopalatine) ganglion. Postganglionic fibres from the latter pass through orbital and pharyngeal branches of the ganglion and the former supply secretomotor fibres to the lacrimal gland while the latter supply the structures in the pharynx. The preganglionic fibres which accompany the ninth nerve pass through its tympanic branch and then by way of lesser (superficial) petrosal nerve they form synapses with the otic ganglion from where postganglionic fibres arise and pass

·ough the auriculotemporal nerve and supply secretomotor fibres to the parotid ınd. The preganglionic fibres which accompany the tenth nerve supply most of e organs of the thorax and abdomen through various plexuses and ganglia on e walls of the individual viscera and are distributed as follows:



— ··· The sympathetic and the parasympathetic innervations of the organs (Diagrammatic).

Heart. Its musculature receives inhibitory fibres but the coronary vessels receive constrictor fibres.

Lungs. The bronchial muscles receive constrictor fibres. (See nerve supply of lungs).

Oesophagus. The lower part of the oesophagus receives motor fibres.

Stomach and intestines. The stomach and intestines up to the right two-thirds of the transverse colon receive accellatory fibres while the sphincters of the stomach receive inhibitory fibres, and its glands, secretomotor fibres, and its blood vessels, vasodilator fibres.

Pancreas. It receives secretomotor fibres and its blood vessels vasodilator fibres.

Sacral outflow. The preganglionic fibres of the sacral outflow leave the spinal cord through the anterior roots of the second and third and the fourth sacral nerves as pelvic visceral or splanchnic nerves or nervi errigentes and after a considerable course along the walls of the blood vessels they form synapses with peripheral ganglia situated on the walls of the individual organs of the pelvic cavity. The fibres distributed to the pelvic organs are as follows:

Rectum and large intestine (up to left half or one-third of the large intestine). They receive accellatory or motor fibres but their sphincters receive inhibitory fibres.

Bladder. Its musculature receives motor fibres whereas its sphincter receives inhibitory fibres.

External genitalia. The external genital organs receive vasodilator fibres.

THE CUTANEOUS SYSTEM

THE SKIN

As the mucous membrane forms a protective covering of the internal passages (mouth, oesophages, intestines etc.) so the skin forms the generalised protective coverings over the body surfaces externally. Around all natural orifices the skin becomes continuous with the mucous membrane lining those orifices and the junction between the two is known as muco-cutaneous junction.

Surface area. In the adult male, the skin forms about 1·8 sq. m. in surface area whereas in the adult female it is about 1·6 sq. m.

Thickness. The thickness of the skin varies considerably from place to place. It is usually thicker on the extensor surface than on the flexor surface. In the palm of the hand, sole of the foot, interscapular region and in the back of the neck it varies in thickness between 3 and 6 mm. It is thinnest over the tympanic membrane and is less than 0·5 mm. in thickness. It is also comparatively thin over the eyelids, penis, bony bridge of the nose and over the root of the nail. The rest of the skin generally varies between 1 and 2 mm. in thickness.

Fig. 880. The skin of the palm of the hand of a student.

Fig. 881. The skin of the palm of the hand of a manual worker.

N.B. In some individual there may be complete absence of pigments and the condition is called *complete albinism*; when partially present it is called *partial albinism*. Localised pigment free areas either from birth or acquired afterwards due to depigmentation are called *leucoderma*,; concentration of pigments in minute spots are called *pigmented moles*.

nective tissue and are responsible for making the superficial surface of the dermis most irregular, a means which increases the surface area of the vascular corium by many times and thereby the avascular cutis (epidermis) comes in more intimate contact with the vascular corium on which it is dependent for its nutrition (the tissue fluid from the corium diffuses into the cells of the epidermis). The number of the

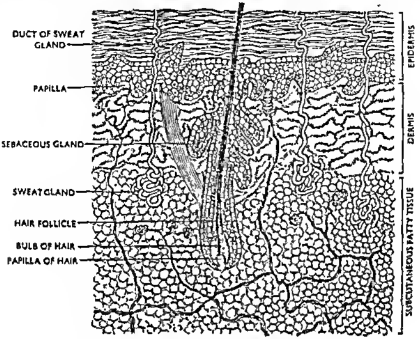


Fig. 883. The structure of skin (Diagrammatic).

dermal papillae vary considerably in different parts of the body; thus in the palm of the hand and in the sole of the foot their number increases considerably where they are arranged in rows, in rows of pairs. Their prominence produces elevations on the surface of the epidermis in those situations and are known as *papillary ridges* which are arranged in definite pattern such as loop, whorl, circle etc. Although the general architecture may be the same the papillary ridge patterns are never alike in two individuals in their finer detail and therefore finger prints showing papillary ridge patterns are taken into consideration in personal identity and in fact they are taken as one of the surest proof of personal identity.

N.B.—In old age the elastic fibre of the skin undergo senile degeneration for which the elasticity of the skin is lost, and with the wasting of the muscles, the skin cannot adapt itself to the reducing girth, and as a result, the skin becomes wrinkled, a feature of the old mans skin. When the skin is overstretched due to pressure of a tumour, or in case of females, due to pressure caused by the growing foetus during pregnency, the connective tissue corium ruptures internally and later on becomes healed up by formation of scar tissue which shows through the epidermis as white linear patches. These white lines on the abdomen in cases of females which result after pregnency are known as *striae gravidarum*.

Vascular supply of the skin. The skin is comparatively rich in blood vessels because it has much to do in the regulation of the body temperature. The avascular epidermis forms a barrier between the vascular dermis and the exterior and acts as a membrane through the medium of which exchange of temperature between the blood and the exterior takes place. As a special measure for temperature regulation peculiar type of circulation in the form of arterio-venous anastomosis is found in the skin. Under certain conditions such as in cold atmosphere the plain muscle surrounding the branch of the terminal arteriole which joins the vein directly, relaxes, so that, the circulation is speeded up via the short circuited arterio-

venous anastomosis (the normal circulation through the capillaries to the veins takes a longer time than the short circuit circulation through the arterio-venous anastomosis). The following is the mode of artery supply to the skin.

The arteries supplying the skin arrange in a plexiform network, *over the superficial fascia*, the *subcutaneous plexus*, and from this plexus fresh vessels arise which penetrate through the deep part of the dermis to reach the subpapillary region where they arrange in another network known as the *sub-papillary plexus*. Terminal arterioles from the sub-papillary plexus penetrate into the papillae where they break up into capillary bed and are arranged into characteristic capillary loops. At places the terminal arteriole provides a branch which communicates directly with the vein and establishes arteriovenous anastomosis.

The blood from the capillaries is returned by venules and veins respectively.

Lymphatics of the skin. The epidermis, being avascular, has no lymphatics. The dermis is drained by three sets of lymph vessels, superficial, intermediate and deep. The superficial sets drain the superficial surface of the dermis and arrange in a plexiform network in the sub-papillary region. From there the lymph vessels pass to the intermediate set which drain the intermediate zone of the dermis. Lymph vessels from there pass to the deep set which is situated in the deeper zone of the dermis and on the superficial fascia. Collecting vessels from the deep set pass along the course of the superficial veins and end into the corresponding lymph nodes.

N.B.—In elephantiasis of the limb due to obstruction in the corresponding lymph nodes the superficial group of lymph vessels draining the skin and the subcutaneous tissue cannot empty their content and as a result the skin becomes hypertrophied and thickened. Anatomically the superficial lymphatics do not communicate with the deep lymphatics (lymph vessels draining the structures beneath the deep fascia) at the periphery except close to their termination in the lymph nodes. Advantage of this knowledge is taken in the surgical treatment of elephantiasis where some portion of the deep fascia is removed so that the superficial lymph vessels will be able to gain access to the deep lymphatics by removal of the deep fascia barrier.

Nerve supply of the skin. The skin is supplied by the *somatic sensory nerves* (cutaneous nerves) and by the *sympathetic nerves*.

Sympathetic nerves. The sympathetic nerve fibres accompany the cutaneous nerves and supply the *secretomotor fibres* (cholinergic fibres) *to the sweat glands*, *vasomotor fibres* (adrenergic fibres) *to the cutaneous blood vessels* and *motor fibres to the arrector pili muscles of the hair follicles*.

Somatic sensory or cutaneous nerves. The sensory nerves of the skin are numerous and are mainly concerned with the perception of different types of sensations such as cold, heat, pain, touch and pressure sensations which the skin can perceive through their medium. The nerves arrange themselves in the form of plexuses from which nerve filaments with different types of characteristic ends (for the reception of the specific type of sensation) are distributed to the different parts of the skin. The cutaneous nerves usually form three plexuses, the *sub-cutaneous*, *sub-papillary* and the *sub-epithelial* plexus from which the nerve filaments are distributed. The different types of nerve endings (also called end organs) that are commonly found in the skin are as follows:

(1) *Pacinian corpuscles.* These are oval bodies consisting of concentric layers of lamellated connective tissue which are pierced at one pole by a medullated nerve fibre and resemble a tadpole in gross appearance. The medullated nerve fibre after its entrance into the corpuscle loses its medullary sheath and ends within it in an expanded extremity. The pacinian corpuscles are the largest of all sensory end-organs and are just visible to the naked eye. Each corpuscle varies from 1 to 4 mm. in length and in breadth it may be as broad as 2 mm.

Distribution. In the skin they are usually found in the subcutaneous tissue. They are also found in the tendon of muscle, capsular ligament of the joints, in the walls of the blood vessels, in the walls of the mesentries of the abdominal viscera as well as in the periosteum.

Functions. In the skin they act as receptors of the pressure sensations whereas

in the joints and in the tendon of muscles they are concerned with the deep proprioceptive sensation (joint and muscle sensations).

Meissner's corpuscles. These are cylindrical encapsulated bodies consisting of transversely disposed connective tissue lamellae and epithelial cells, around which the medullated nerve fibre ends by winding like a serpent. The nerve fibre loses its medullary sheath as it pierces through corpuscle and finally ends by ramifying around the epithelial cells within the corpuscle.

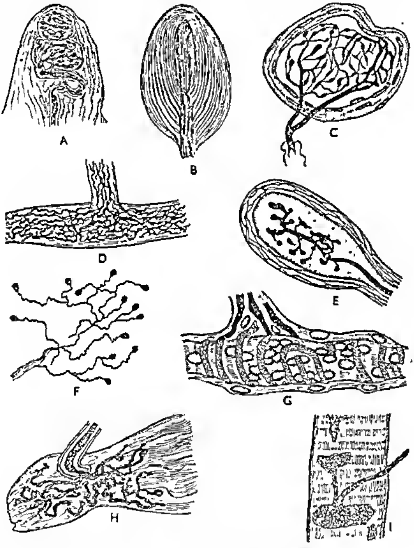


Fig 884 A few nerve endings A—Tactile or Meissner's corpuscle. B—Pacinian corpuscle. C—End-bulb of Krause. D—Organ of Ruffini. E—Organ of Golgi-Mazzoni. F—Free nerve terminals. G—Muscle spindle. H—Golgi bodies (Organ of golgi). I—End plates.

Distribution and function. They are usually found in the dermal papillae and on the superficial aspect of the dermis. Functionally they are concerned with the perception of the light touch sensation.

Krause's end organ. Here the terminal end of the nerve ends in ramifications which are arranged in ball-like rounded body resembling flower in appearance which is surrounded by a connective tissue capsule.

Distribution and function. They are mostly found in the skin surrounding the nipple and the external genitalia. They are supposed to be concerned with the cold sensations.

Ruffini's Body. This is essentially a form of free endings in which the nerve fibre, which has lost its medullary sheath, is arranged in the form of a tuft of fine filaments. It differs from the other end-organs in that it has no capsular investment over its terminal filaments.

Distribution and function. These bodies are present in the dermis and are concerned with the appreciation of the sensation of warmth.

Free medullated and non-medullated nerve endings. Medullated and non-medullated nerve fibres (fibres which have lost their medullary sheath) are also found to be widely distributed in the different parts of the skin. Some of them are found to be distributed in the epidermis, some are found to form intricate plexuses beneath the epidermis (sub-epidermal) and in the dermis and some are found to be distributed over the epithelial cells of the hair follicle.

Functions. Free endings in the epidermis and in the hair follicle are concerned with the sensation of light touch. Sub-epidermal and dermal free endings are concerned with painful sensations.

Appendages of the skin. Hairs, glands and nails in particular situations grow in the skin in its process of development and as such they are taken to be the integrated parts of the skin and are usually described as appendages of the skin. The following is a brief outline of these structures.

Hairs. Hairs are present everywhere except in the skin of the penis, palm of the hand, sole of the foot, red margins of the lips, umbilicus, labia minora and in the skin of the medial portion of the labia majora. Males are usually more hairy than the females but in the latter the growth of hairs is more luxuriant in certain parts of the body, i.e., in the *scalp*. Hairs in the form of moustaches and beards are the most important secondary sexual characteristics in the males whereas they are wanting in the females. Racial peculiarities are also noticed in hair growth thus the Mongolians are characteristically found to have scanty hairs whereas some of the Australians are seen to be more hairy.

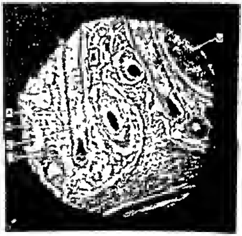


Fig. 885. A section of the scalp showing the hairs in cross and longitudinal sections (Microphotograph).

A = outer root sheath
B = Inner root sheath
C = Hair shaft
D = A hair in cross section
E = Hair papilla

Parts of a hair. Each hair consists of a shaft, a root and a bulb and is ensheathed in an epidermal pit known as the *hair follicle.* The portion of the hair that projects outside from the surface is called its *shaft* whereas the portion that penetrates into the substance of the skin is known as its *root.* The root terminates into a bulbar swelling within, known as the *bulb of the hair* which is surrounded by a soft whitish material known as the *germinal matrix* which is responsible for the growth of the hair.

The hair follicle. The hair follicle is the flask-like epithelial pit into which the hair root is received. The bottom of the follicle rests on a vascular papilla of the dermis known as the *hair pipilla* which invaginates the bottom of the follicle. Each hair follicle, as it is formed by invagination of the epidermis into the dermis, is surrounded by the connective tissue corium and thus consist of two layers, outer layer of corium or dermis and inner

epidermis. The walls of the hair follicle show sidewards irregular evaginations which form the *sebaceous glands*. The *arrector pilorum* muscle (plain muscle fibres, which extend from the epidermis, are attached to the outer dermal layer of the follicle close to its base. The muscle is usually attached to the side to which the hair shows its natural bending. The muscle is known as the arrector pilorum or *hair muscle* and acts from the epidermis. By its contraction it raises the hair follicle towards the surface of the skin and as a result the hair stands erect and there becomes a dimple on the surface of the skin corresponding to the site of attachment of the muscle to the epidermis.

Structurally the epithelial wall of the hair follicle consists of polygonal cells which towards the surface of the skin are arranged into several layers but near the bulb of the hair they are much thinned out and are made up of a single layer of polygonal cells and constitute the *outer root sheath*. Then the cells are reflected on to the root of the hair to form the *inner root sheath* and become continuous with the hair bulb.

Structure of hairs. Structurally the hair shaft and its root differ from each other in some detail and they are dealt separately as follows:

Hair shaft. The hair consists of an outer cortex and inner medulla. The cortex is made up of elongated, fusiform and keratinized cells with longitudinal fibrils which still show the presence of nuclei and form the fibrous basis of the hair. Surrounding the fibrous cortex is the epithelial cuticle formed by the transparent cornified epithelial cells which are scale-like and are arranged side by side with their free edges directed towards the surface. The medulla of the hair is occupied by the medullary cavity which is usually filled up with some irregular cells. The colour of the hair is dependent on the amount of melanin pigment present in the cells of the cortex as well as on the condition of the medullary cavity. In old age the cells of the medullary cavity undergo atrophic degeneration and the medullary cavity becomes filled up with air bubble, and as a result, in transmitted light, the hair looks grey.

The *hair root* terminates into a bulbous extremity which is known as the bulb of the hair. The hair bulb consists of polygonal and columnar cells which are in active state of proliferation. By their growth and proliferation more mature cells are displaced towards the hair shaft and as they pass towards the latter they become cornified. The bulb of the hair rests on the summit of a vascular papilla on which it is dependent for its nutrition.

Functions of hairs. In some animals hairs are primarily concerned with the maintenance of body heat and at the same time they protect the body from the exposure of cold and heat. In man, except those on the scalp, their value in the regulation of body heat is negligible. The hair pores in man subserve the function of lubricating channels through which the sebaceous glands pour out their discharges on to the surface of the skin and keep it soft and pliant. As in some animals hairs are protective so in man they also serve the protective function at certain situations such as the nostrils, external ear and the eyelid (eye lashes). Hairs undoubtedly are of cosmetic value in that they add to the beauty of the human body. They also subserve to some extent sensory functions in being the instruments of tactile sensations.

Sebaceous glands. The sebaceous glands are the alveolar type of glands which develop as diverticula of the hair follicle except in places like the red margin of the lips as well as some parts of the external genitalia where they grow independently of the hair follicle. They are found everywhere in the skin except that of the palm of the hand and the sole of the foot. Each gland is surrounded by a connective tissue investment derived from the corium and presents a small duct which opens usually into the lumen of the hair follicle and in places where they grow independently of the bair follicle, the duct ends by opening directly into the skin surface.

The alveoli of the glands are formed by solid masses of cells which are derived from the polygonal cells of the basal layer of the epidermis. The cells contain fat granules in their cytoplasm and these granules gradually increase as the cells

approach the centre from the periphery. Those at the extreme centre show the presence of a large fat droplet, presumably formed by coalescence of the fat granules found in the more peripherally placed cells, which distend the cell enormously. Ultimately the cell undergoes fatty disintegration in which the cell ruptures and becomes fragmented. Thus the fatty material together with the disintegrated cell, which form the sebum, is poured out into the lumen of the duct which carries the sebum to the skin surface. The secretion of sebaceous glands has no nervous control and it continues even after lesion of the regional nerve. Judging from the mode of secretion, the sebaceous glands fall under the sub-group of holocrine gland in which the secretion is effected by complete disintegration of the cell.

Functions of the sebaceous glands. The functions of the sebaceous glands are attributable to the sebum, the secretion of the gland. The oily nature of the sebum affords to form the medium of lubrication for the skin and the sebaceous glands by constantly pouring out their discharges in the form of sebum keep the skin greasy, soft and pliable. This oiling and greasing mechanism of the skin by the sebaceous glands brings forth water-proofing effect to it and at the same time it helps in removing the constantly decaying epithelial cells on the surface of the skin. It is believed that the sebum afforts nutrition to the hair shaft and that it contains bactericidal substances which increase local immunity.

Sweat glands. These are simple tubular glands which extend from the dermis in between two dermal papillae and end by opening into the skin surface. Each gland consists of a secretory part which is coiled and is placed in the deeper part of the dermis or sometimes extends even upto the subcutaneous fascia, and an excretory part or the duct which carries the secretion to the skin surface. The duct is usually spirally twisted which ends by opening into the skin surface.

Sweat or sodoriferous glands are present in all parts of the skin except the red margins of the lips ond some parts of the external genitalia (prepuce, glans penis) and they are specially abundant in the region of the palm of the hand and the sole of the foot.

Structurally the secretory part of the gland consists of cubical cells which rest on a layer of epitheloid cells which behaves like a muscular tissue and is known as *myoepithelial cells*. The duct is also lined by cubical cells.

Depending on the mode of secretion, the sweat glands may be sub-divided nto epicrine and apocrine type of glands.

The epicrine type of sweat glands are widely distributed in the skin of the body and are concerned with the secretion of sweat consisting mainly of water, sodium chloride and urea. They are comparatively smaller glands than the apocrine type and are of simple tubular type. Their secretion is effected without any loss of substance of the secretory cells. The secretion of the cells permeates through the cell membrane and appear on the free surface of the cells as dew-drops.

The sweat glands of the axilla, external acoustic meatus, scrotum and perianal region, and in the female, labia majora and of mons pubis are of apocrine type in which the superficial part of the cell substance is shed away along with the secretory substance which usually cause vesicular swelling of the cells towards their free surfaces. Regeneration of the cell takes place through the activity of the remaining portion of the cell. They are comparatively larger glands with longer ducts and may be of branching type. Their secretion is more concentrated than that of the epicrine type and is of variable composition. The secretion has also characteristic odour.

The sweat glands of the external acoustic meatus pour out their secretion as cerumen which is a sticky, viscid substance and they are known as *ceruminous glands*. The sticky and the viscid nature of the secretion in the external acoutsic meatus is a protective device to the delicate tympanic membrane. The dust particles that gain access to the external acoustic meatus are enatangled by the sticky cerumen and thus the delicate tympanic membrane is protected from dust-injury.

Functions of the sweat glands. The functions of the sweat glands are attributable to the secretion of the epicrine type of the glands (sweat). Th.

important function of the sweat is the *temperature regulation* by the process of evaporation from the cutaneous surface. In addition, the sweat forms the vehicle of excretion (elimination) of waste products, sodium chloride and water. Excessive sweating leads to the loss of enormous quantity of sodium chloride from the blood which gives rise to painful muscular cramps.

The functions of the apocrine type of the sweat glands, except the ceruminous glands of the external acoustic meatus, are still unknown definitely. It is likely that the characteristic odour of their secretion rouses sex desire in either sexes. The discharges of the ceruminous glands protect the tympanic membrane from injury (see above) by inseects and dust particles etc.

Nervous control of the sweat glands. The sweat glands are supplied by the sympathetic nerves (cholinergic fibres) which are controlled by the sweating centers in the central nervous system (hypothalamus, medulla, spinal cord). The sweating centre gives rise to impulses which are carried through the peripheral sympathetic nerves to the sweat glands which are stimulated to secrete. Slightest rise of body temperature, emotional excitement and physical exercises, stimulate the sweating centres so as to induce sweating.

N.B.—The sympathetic fibres are usually adrenergic but those supplying the sweat glands are cholinergic (exception) i.e., instead of forming adrenalin they form acetylcholine when stimulated (the nerve impulse, depending on the nature of the nerve, either forms adrenalin or acetylcholine at the nerve terminals which is the chemical transmitter of nerve impulse to the tissues. Usually the sympathetic nerve produces adrenaline whereas the para-sympathetic nerves produce acetylcholine at the nerve terminals when stimulated).

Nails. The nails are flattened, hard and modified form of epidermal condensations, occupying the dorsal aspect of the terminal digits of both fingers and toes. Each nail lies on a corrugated bed formed by the dermis and the Malpighian layer of the epidermis known as the *nail bed.* On either side is a furrow between the nail margin and the skin fold and is known as the *nail groove.* Distally each nail ends in a free border which grows out beyond the distal skin fold and the narrow cleft between it and the distal skin fold is known as the *hyponychium.* Proximally a portion of the nail which is overlapped by a fold of skin is called the *nail root* and the overlapping fold of skin is known as the *nail fold.* The portion of the *nail* that extends distally beyond nail root is known as the *nail shaft or body.* The nail shaft is transparent in the greater part of its extent except over a small white semilunar area just distal to the nail fold where it is opaque and is sharply demarcated from the transparent area which presents a red glow due to the underlying blood vessels. The white semilunar area is known as *lunula.* Functionally the lunula overlies the germinal portion of the nail bed which is concerned with the nail growth while the transparent part overlies the portion of the nail bed which has no concern with the nail growth and is often called the *sterile portion* or *sterile matrix* of the nail bed. Clinically the degree of intensity of the red glow through the transparent portion is taken into account as a measure of rough estimate about the degree of anaemia.

When the skin of the nail fold is traced to the nail, layer by layer, it is found that the stratum corneum extends to the root of the nail only for a short distance and is deficient to the rest of its extent. The small extension of the stratum corneum over the nail root constitutes the *eponychium.* The stratum lucidum of the nail fold is not only continuous with the nail but it forms the main bulk of the nail in a modified form. The stratum granulosum and the stratum Malpighium are continuous with the epithelial covering of the nail bed.

The *nail bed* is made up of both dermis as well as the epidermis. The dermal papillae in the nail bed are arranged in longitudinal linear ridges which make a corrugated surface on the top of which the two epidermal layers, the stratum Malpighium and the stratum granulosum, are closely applied. As already pointed out the epithelium of the nail bed can be divisible into two portions, the germinal portion, which underlies the lunula and the sterile portion, which underlies the transparent part of the nail shaft. The granules of the cells of the stratum granulosum are

specially modified to form the *onchogenic granules* from which the horny matrix of the nail is formed.

Development of the skin. The skin is a composite structure and is made up of both ectoderm and mesoderm. The epidermis is formed by the ectoderm while the dermis is formed by the mesoderm.

During the earlier part of development, the embryo is covered only by a single layer of epithelial cells derived from the ectoderm. At about the end of the fourth week of foetal life the epithelial covering can be divisible into two layers, superficial and deep. The superficial layer is known as the *epitrichium* whereas the deep layer forms the *germinal* or *basal layer*. By the third month, the superficial layer or the epitrichium is shed away while the deep germinal layer, which is left alone, becomes much proliferated to be differentiated into three layers, basal layer, intermediate layer and the superficial layer. The basal layer consists of a single layer of columnar cells, the intermediate layer consists of polygonal cells of several cells deep while the superficial layer consists of flattened cells which form the stratum corneum. During the fifth month, further differentiation takes place to form the *stratum lucidum* which intervenes between the stratum corneum and the intermediate layer.

The hair follicle, hair, hair muscle and the sebaceous glands. The hair follicle develops as a solid inward growth of the epidermal cells which penetrate through the dermis so as to have a nailing effect. All the layers of the epidermis except the epitrichium take part in the inward growth and the cells at the bottom of the growth (those opposing the dermis) are formed by the cells of the stratum germinativum. Opposite the centre of the epithelial growth the cells become locally proliferated so as to form a knob-like thickening which represents the bulb of the hair. At the site of the contact between the hair bulb and the mesodermal corium the cells become condensed to form the vascular hair papilla which soon invaginates into the hair bulb. The cells of the hair bulb that overlie the hair papilla are of columnar type and make the basis for the formation of the hair. Active proliferation of these cells give rise to the formation of a hair bud which bores through the solid epithelial in-growth and forms the hair.

As the hair bud gradually approaches the surface of the skin the cells become more and more cornified and ultimately the cells of the hair shaft become completely keratinized. As the hair bud bores through the solid hair follicle it receives cellular investment from the cells on the wall of the hair follicle as inner and outer root sheaths (already described).

The hair muscle or the arrector pilorum is of ectodermal origin (exception) ind is derived from the cells on the wall of the deeper part of the hair follicle.

The sebaceous gland, also develop as a solid out-growths from the wall of the hair ollicle except in the red margins of the lips and penis where they grow from the :ctoderm independently of the hair follicle.

By the third month, the hairs first appear on the eyelids, eye brows, lips and .he scalp and by the fourth month they usually appear in the rest of the body although new hairs come up even until birth. Sexual hairs, that is, those in the axilla, pubis and the face appear during puberty.

Nails. Developments of the nails have already been discussed.

Sweat glands. They appear first during the fourth month as solid epidermal in-growths through the dermis and soon become canalised to form the tubular type of gland. They occasionally arise from the neck of the hair follicle.

Functions of the skin as a whole. Functions of the skin may be considered under the following heads:

(1) *It is a protective insulation over the body.* If an animal's skin is taken off it dies in no time due to profound shock resulting from exposure of the nerve endings and loss of fluid. Infecting organisms cannot penetrate through unbroken skin and thus it acts also as a *protective membrane against bacterial invasion.* Moreover it acts as a *waterproof for the body* due to the presence of the greasy sebum on its surface.

(2) *It is a sensory organ.* The sensory nerves of varying functions being integrated into the skin the latter acts as a sensory organ by which one becomes conscious about its external environment.

(3) *It regulates the temperature of the body.* The dermis being extremely vascular and the epidermis over it being extremely thin dissipation of heat can easily take place between the blood and the exterior.

(4) *It is an excretory organ.* The sweat glands of the skin excrete water, sodium chloride and urea through their excretion as sweat. By eliminating water it also *helps in keeping water balance of the body.*

(5) *It is a reservoir of vitamin D.* Ergosterol, a precursor of vit. D, being activated by the ultraviolet ray on the surface, is converted in to vit. D, an anti-rachitic vitamin.

(6) *It is a reservoir of food.* The fats of the true skin and the subcutaneous tissue are utilised as food during some strained circumstances particularly during starvation.

THE ORBIT AND THE EYE BALL

The orbit is the funnel-shaped hollow cavity in which the eye ball, its muscles, vessels and nerves and the lacrimal gland are contained. Its *base* corresponds with the orbital margins whereas its *apex* corresponds with the optic foramen. Besides an apex and a base it has a floor, a roof, a medial wall and a lateral wall.

Measurements:

Antero-posterior	$1\frac{3}{4}$ inches
Vertical (at the base)	$1\frac{1}{4}$ inches
Horizontal (at the base)	$1\frac{1}{2}$ inches

Boundary.

The roof. The roof is triangular and concave. It is formed by the orbital plate of the frontal bone in front and by the small wing of the sphenoid behind and separates the orbital cavity from the anterior cranial fossa. Posteriorly the lesser wing of sphenoid presents the optic foramen for the optic nerve and the ophthalmic artery. Midway between supraorbital notch and nasolacrimal suture (antero-medially) there is a fovea or a spine (fovea vel spina trochlearis) for the attachment of fibrocartilaginous pulley of the superior oblique muscle of the eyeball. Antero-laterally it presents a depression for the accommodation of the lacrimal gland.

The Floor. It is formed mainly by the orbital surface of the maxilla; in front and laterally, it is formed by orbital process of the zygomatic bone, and behind and medially, by the orbital process of the palatine bone. It separates the orbital cavity from the maxillary air sinus. In the medial angle is the upper opening of naso-lacrimal canal, lateral to which, a depression on the orbital surface of the maxilla gives origin to obliquus oculi inferior. In the middle of the floor is the infraorbital groove or canal for the infraorbital vessels and nerves.

Medial wall. The medial wall of the orbit is quadrilateral in shape and thus it differs from the other walls which are triangular. The medial walls of the two orbits are approximately parallel to each other. It is formed by the frontal process of the maxilla behind the anterior lacrimal crest, the lacrimal bone, small part of the frontal bone directly above it, orbital plate of the ethmoid and by a small part of the body of the sphenoid in front of the optic foramen. This wall separates the orbital cavity from the ethmoidal air sinuses and from the anterior part of the sphenoidal air sinus. At the junctions of the medial wall and the roof there is a groove for the lacrimal sac. Behind it, the posterior lacrimal crest gives attachment to the lacrimal fascia and the lacrimal head of the orbicularis oculi. In the fronto-ethmoidal suture are the anterior and posterior ethmoidal foramina for the corresponding vessels and nerves.

Lateral wall. It is formed by the orbital surface of the zygomatic bone and the orbital surface of the greater wing of the sphenoid. On the orbital process of the zygomatic about 11 mm. below the fronto-zygomatic suture is the orbital tubercle (Whitnol) for check ligament of the rectus lateralis, part of the aponeurosis of the levator palpebrae superioris, suspensory ligament of the eyeball, and the lateral palpebral ligament. The zygomatico-orbital foramina transmit the corresponding vessels and nerves. At the junctions of the roof and the lateral wall there lies the superior orbital fissure which transmits the oculomotor, trochlear, and abducent nerves and the three branches of the ophthalmic division of the trigeminal nerve, a few filaments from the cavernous plexus of sympathetic nerves, the orbital branch of the middle meningeal artery, recurrent meningeal branch of the lacrimal artery and the ophthalmic veins. At the junction of the lateral wall and the floor, the inferior orbital fissure transmits the maxillary nerve, inferior orbital vessels and nerves, zygomatic nerve and a few filaments from the pterygopalatine (sphenopalatine) ganglion to supply the periosteum of the orbit.

Base. It is formed by the supraorbital margin of the frontal bone above and the infraorbital margin of the maxilla below, orbital margin of the zygomatic bone laterally and the anterior lacrimal crest medially.

Apex. This corresponds to the optic foramen through which the optic nerve and the ophthalmic artery pass.

Contents of the orbital cavity. It contains the peripheral organ of sight, the eyeball surrounded by ocular muscles and fascia, a quantity of fat and a few vessels, nerves and lymphatics of the eyeball.

The eyeball is embedded in the fat of the orbit but is separated from it by a membranous structure, the fascia bulbi. The central point of the anterior curvature of the eyeball is known as the anterior pole whereas the central point of the posterior curvature is known as the posterior pole.

The *orbital fascia or the periorbita.* It forms the periosteum of the orbit and is loosely applied on the different walls of the bony socket. Behind, it is blended with the dura mater and the sheath of the optic nerve. It gives two septa, one of which holds the pulley for the superior oblique muscle of the eyeball and the other bridges over the lacrimal groove forming the lacrimal fascia and covering the lacrimal sac.

The fascia bulbi. It is a thin membrane which envelops the bulb of the eye from the apex to the base separating it from the orbital fat and forming a socket within which it plays. It is separated from the sclera by episcleral space which is traversed by the delicate connective tissue bands connecting the two. The fascia is perforated by the ciliary vessels and nerves. In front it blends with sclera just behind the sclero-corneal junction. Piercing it pass the tendons of the ocular muscles, each of which receives a sheath from it. The expansion from rectus superior blends with the tendon of levator palpebrae superioris. The expansions from rectus medialis and lateralis check the action of these two recti muscles and they are called medial and lateral check ligaments respectively.

Muscles—

Levator palpebrae superioris. It arises from the under-surface of the lesser wing of the sphenoid above and in front of the optic foramen. From its origin, as it passes forwards, it becomes expanded and ends in an aponeurosis which splits up into two lamellae, upper and lower. The upper one blends partly with the upper tarsal plate and partly with the skin of the upper eyelid and the lower one with the anterior surface of the upper tarsal plate.

Four recti. All of the four recti arise from the annulus tendineus communis, a fibrous ring, which is attached to the upper, medial, and lower margins of the sheath of the optic nerve on the medial side and to the tubercle on the medial margin of the orbital surface of the greater wing of the sphenoid on the lateral side. It transmits the optic nerve, ophthalmic artery, superior and inferior divisions of the oculomotor nerve, the nasociliary and abducent nerves. The superior or inferior ophthalmic veins may pass through it. Both superiorly and inferiorly the ring presents a specialised band. The superior one, tendon of Zinn, gives origin to rectus superior, part of the rectus medialis and lateralis; the inferior part, superior tendon of Lockwood, gives origin to rectus inferior, rectus medialis and lateralis. Each muscle from their origin passes forwards to their respective position on the eyeball and is inserted by tendinous expansion into the sclera about one-fourth inch behind the sclero-corneal junction.

Obliquus oculi superior. It arises from the tendinous ring above the optic foramen and lies supero-medial to the origin of the rectus superior and passes forwards to end into a rounded tendon which plays in a fibro-cartilaginous pulley attached on the fovea vel spina trochlearis of the frontal bone and then passes backwards, laterally and downwards to be inserted into the sclera between rectus superior and rectus lateralis.

Obliquus oculi inferior. It arises from a small depression on the orbital surface of the maxilla immediately lateral to the naso-lacrimal groove; it passes upwards,

backwards and laterally and is inserted into the sclera between the rectus superior and rectus lateralis and behind the attachment of the obliquus-oculi superior.

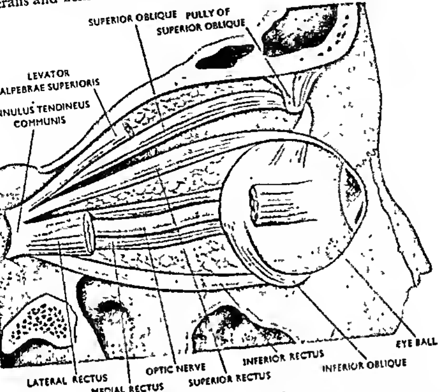


Fig. 886. The ocular muscles

Nerve supply. All the muscles of the eyeball are supplied by the oculomotor nerve except the rectus lateralis which is supplied by the abducent nerve and the obliquus oculi superior which is supplied by the trochlear nerve.

Actions. Levator palpebrae superioris raises the upper eyelid. The rectus medialis et lateralis act around vertical axes and rotate the eyeball medially and laterally respectively. The rectus superior acting singly rotates the eyeball upward and medially; but acting with the inferior oblique it elevates the eyeball directly upwards. The inferior rectus acting singly rotates the eyeball downwards and medially but while acting with superior oblique it directly depresses the eyeball. Thus both the superior and inferior recti owing to their slight obliquity towards the lateral side both of them cause some amount of adduction which is corrected by the oblique muscles as stated above. The obliquus superior rotates the eyeball so as to turn it downwards and laterally. The obliquus inferior moves the eyeball so as to turn its corneal surface upwards and laterally. The movement of circumduction, as in looking round an object, is performed by the four recti acting successively.

Disposition of other structures within the orbit—

(1) The frontal nerve, a branch of the ophthalmic division of the trigeminal nerve, lies over the levator palpebrae superioris opposite the median axis of the eyeball and divides into supraorbital and supratrochlear branches of which the former is lateral to the latter.

(2) The trochlear nerve lies at the medial end of the superior orbital fissure on the medial side of the frontal nerve and lies in close contact with the orbital periosteum and by crossing superficial to the origin of the rectus superior and levator palpebrae superioris it enters the ocular surface of the superior oblique muscle.

(3) When the lavator palpebrae superioris which lies immediately below the frontal nerve, is divided between its origin and insertion, the nerve to the same muscle from the superior division of the oculomotor nerve is seen to enter the deep surface of its posterior half.

(4) The rectus superior lies immediately below the levator palpebrae superioris and when it is

reflected in the same way the superior division of the oculomotor nerve is seen to enter the deep surface of its posterior half.

(5) The lacrimal branch of the ophthalmic nerve passes to lacrimal gland opposite the junction of its roof and lateral wall.

(6) As soon as the levator palpebrae superioris and the rectus superior are reflected the optic nerve surrounded by fascia bulbi is exposed.

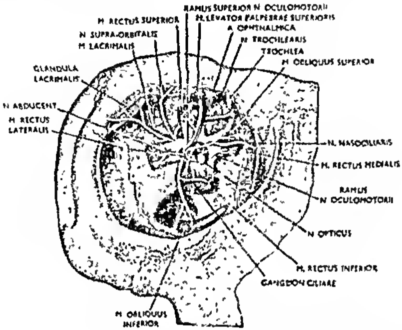


Fig. 807. The annulus tendineus communis and muscles and nerves in relation to it.
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(7) The posterior part of the optic nerve is seen to be crossed by superior ophthalmic vein, ophthalmic artery and the nasociliary nerve from lateral to medial side, the nasociliary nerve intervening between the two divisions of the oculomotor nerve.

(8) Immediately on the lateral side of this part of the optic nerve and usually lying on the ophthalmic artery, is the ciliary ganglion which resembles a large pin-head. The ciliary ganglion is joined from behind by the sensory root from the nasociliary, motor root from the nerve to the inferior oblique muscle of the eyeball and by sympathetic root from the carotid plexus of sympathetic. Pull the nasociliary nerve as it crosses the optic nerve and secure the two slender twigs which join the ganglion; similarly, pull downwards the nerve to the inferior oblique muscle and secure its motor root.

(9) Pull the nasociliary nerve as it crosses the optic nerve and secure the two long slender branches which run over the superomedial aspect of the optic nerve. These twigs are the long ciliary branches from the nasociliary nerve. Reaching the anterior part of the medial wall of the orbit the nasociliary nerve breaks up into infratrochlear and anterior ethmoidal branches. The latter passes to the nasal cavity through the anterior ethmoidal canal.

(10) The ciliary ganglion gives rise to numerous slender nerves, the short ciliary nerves which form a plexus on the optic nerve and pass to the eyeball.

(11) The rectus lateralis muscle arises by two heads from the lateral part of the common tendinous ring and lies on the lateral side of the optic nerve.

(12) Passing in between the two heads of rectus lateralis are the superior and inferior divisions of the oculomotor nerve, the nasociliary nerve which lies between the two divisions of the oculomotor nerve, and the abducent nerve which soon enters into the deep surface of the rectus lateralis.

(13) The inferior division of the oculomotor nerve passes downwards, forwards and medially below the optic nerve and it sends out the motor root to the ciliary ganglion immediately after passing in between the two heads of the rectus lateralis and then breaks up into branches which supply the rectus medialis, rectus inferior and the obliquus inferior.

(14) The sympathetic root to the ciliary ganglion from the carotid plexus of sympathetic nerves ·ly follows its motor root and joins it at its posterior part.

(15) When the optic nerve is cut and the eyeball is turned outwards and forwards the inferior rectus and the inferior oblique muscles are seen. Both of them receive their nerve supply from the inferior division of the oculomotor nerve; the nerve to the inferior oblique enters the same muscle through its posterior border which differs in the mode of nerve supply from other ocular muscles in which respective nerve enters the respective muscle through their ocular surface.

(16) The ophthalmic artery crosses the optic nerve from lateral to medial side in company with the nasociliary nerve. It arises from the internal carotid artery opposite the level of the optic foramen and passes through the same lying inferolateral to the optic nerve and enters into the orbital cavity and then soon crosses the optic nerve from lateral to the medial side to reach the medial wall of the orbit. Then it passes to the medial margin of the front of the orbit where it breaks up into its terminal branches, frontal and dorsal nasal.

The ophthalmic veins after receiving numerous tributaries pass backward through the gap between the two heads of the rectus lateralis and soon are joined together to form the cavernous sinus.

THE EYEBROWS AND THE EYELIDS

Eyebrows. These are arched eminences of skin opposite the supraorbital margin of the bony orbit. Thick short hairs make their presence in abundance in this part. Orbicularis oculi, corrugator and frontalis are inserted into it.

Eyelids or palpebrae. These are two, upper and lower, movable shutters of the orbital opening. Each eyelid consists of a tarsal plate formed by condensed mass of connective tissue cells and is covered by the skin on its outer side and the tarsal conjunctiva on its inner side. The upper eyelid is furnished with a levator muscle, the levator palpebrae superioris. The two eyelids meet each other to form the medial and lateral angles on the corresponding side of the eyeball. The lateral angle is more acute than the medial one. When the eyelids are opened the elliptical space between the two lids is known as the palpebral fissure.

On the medial angle the two eyelids are separated from each other by a triangular space known as the lacus lacrimalis; in it there is a small reddish body known as caruncula lacrimalis. On the margin of each eyelid opposite the basal angles of the lacus lacrimalis there is a small papilla termed the lacrimal papilla; in it there lies the opening of the lacrimal canaliculus and this opening is known as the puncta lacrimale.

The margins of the eyelid give attachment to the eye lashes. Near their attachments there are the openings of a number of small glands, the ciliary glands, arranged in rows close to the free margin of the lid.

THE EYE BALL

Eyeball. The eye ball is spheroidal in shape and is placed within the fat of the orbital cavity from which it is separated by the fascia bulbi. It is convex on all sides and it measures about one inch in its transverse and anteroposterior diameters. Its vertical diameter is less than the anteroposterior or transverse diameter. The eyeball, in case of female, is usually smaller than that of the male. The central point of the anterior curvature is called the anterior pole and that of the posterior curvature is called the posterior pole. The line joining the two poles constitutes the optic axis. The optic axes of the two eyeballs run parallel to each other.

Each eyeball consists of three tunics or coats and enumerated from without inwards they are as follows:

(1) *Fibrous tunic* consisting of sclera behind and the cornea in front.
(2) *Vascular tunic* consisting of choroid, ciliary body and iris.
(3) *Nervous tunic* consisting of retina.

The sclera. It is a dense, opaque membranous sheet which forms the spheroidal shape of the eyeball. Anteriorly the sclera becomes continuous with the cornea and the junction between the two is known as the sclerocorneal junction.

Posteriorly it is continuous with the sheath of the optic nerve and the dura mater. Its outer surface is smooth except where it receives the insertion of the ocular muscles where it is rough. Its inner surface looks brownish in colour and is separated from the choroid by the perichoroidal space which is traversed by numerous fine, delicate cellular elements and collectively forms the suprachoroidal lamina. Its inner surface presents a series of delicate grooves for the transmission of the vessels and nerves. Posteriorly the thickest part of the sclera is pierced by the optic nerve and some other smaller vessels and nerves which give it to a cribriform appearance and is called the lamina cribrosa sclerae. Of the smaller openings one is comparatively larger for the transmission of the central artery to the retina. In the midway between the lamina cribrosa sclerae and the sclero-corneal junction there are five or six openings for the passage of the vena voticosae. Just behind the sclero-corneal junction the substance of the sclera presents a circular canal within, known as the sinus venosus sclerae (canal of schlemm). It communicates internally with the anterior chamber and externally with the anterior ciliary vein.

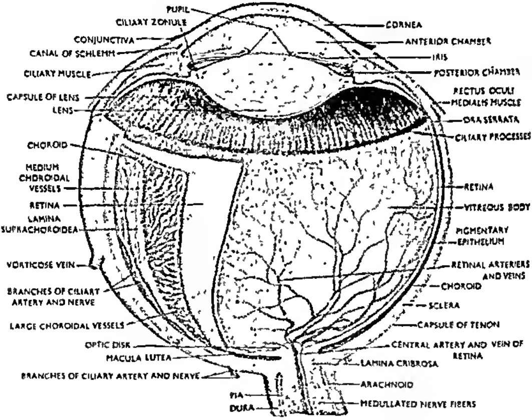

Fig. 888. The anatomy of the tunics of the eyeball. With kind permission from: Lederle Laboratories Ltd. Drawn by Mr. Paul Peck.

The cornea. It forms the non-vascular anterior bulging and transparent part of the external coat. It is circular in form and is continuous posteriorly with the sclera, the junction of which is called the sclero-corneal junction. It maintains the uniform thickness throughout its entire extent. Its anterior surface is convex and bulging while its posterior surface is concave. Interiorly just in front of the sclero-corneal junction the cornea presents a circular rim like elevation, behind which, there is a sulcus called the sulcus circularis cornae. Between this and the attachment of the iris there is an angular recess known as the irido-corneal angle.

The inner posterior elastic lamina of the cornea breaks up into fibres which

orm the trabecular tissue which lines the sulcus circularis cornae and forms the inner lining of the sinus venosus sclerae.

The choroid. It forms a highly vascular membrane consisting of dense capillary plexus of small arteries and veins. Posteriorly it is adherent to the sclera where it is pierced by the optic nerve. Externally it is separated from the sclera by the supra-choroidal lamina. Internally it is lined by the retinal layers.

The ciliary body. It consists of ciliary ring, the ciliary processes and the ciliaris muscle.

The ciliary ring forms the anterior part of the choroid which is distinguished by the absence of the chorio-capillary lamina.

The **ciliary processes.** These are infoldings of the various layers of the choroid. They are arranged in a circle as short processes behind the iris with which it is continuous and projects in front of the lens. Posteriorly, they are connected with the suspensory ligament of the lens.

The ciliaris muscle. It consists of unstriped muscle fibres which contain longitudinal and circular fibres and forms a ring round the outer surface of the anterior part of the choroid. This muscle is the chief or principal agent for maintaining the accommodation of the eye. When it contracts it pulls forward the ciliary processes and as a result, the suspensory ligament of the lens becomes relaxed and the lens adapts itself to be more convex.

The iris. It is a circular contractile disc placed between the cornea in front and the lens behind and is formed by the anterior part of the middle coat of the eyeball. It is perforated a little to the left of its centre by a circular aperture called the pupil. Its periphery is continuous with the ciliary body and also is connected with the posterior elastic lamina of the cornea by the ligamentum pectinatum iridis. The colour of the iris is usually dark black in hue, but it is usual to be different in certain class of peoples where it may be greyish in colour or it may assume some modified colour. The iris divides the space between the lens and the cornea into an anterior and a posterior chamber. The anterior chamber is bounded in front by the posterior surface of the cornea and behind by the anterior surface of theiris, and opposite the central point where the pupil lies, the posterior boundary is formed by the central part of the lens capsule. The posterior chamber is bounded in front by the posterior part of the iris and behind by the lens and its capsule and ligaments. The two chambers communicate with each other through the pupil. Both the chambers contain an alkaline watery fluid, the aqueous humour, secreted by the ciliary processes. The ciliary processes first pour out their secretion in the posterior chamber and then is carried to the anterior chamber through the pupil from where the fluid escapes into the anterior ciliary vein through the sinus venosus sclerae. (Canal of Schlemm

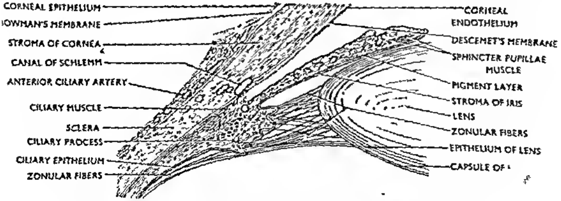

Fig 889. The anatomy of the iridocorneal angle. With kind permission from: Lederle Laboratories Ltd. Drawn by Mr. Paul Peck.

The margin surrounding the pupil is called its pupillary margin while its circumferential margin is called its ciliary margin. It has anterior and posterior surfaces. The anterior surface is directed towards the cornea and presents a striated appearance with the striae converging towards the pupillary margin. The posterior surface is directed towards the crystalline lens and the ciliary processes. This surface is of purple colour and is covered by two layers of pigmented columnar cells which are called the pars iridica retinae and is continuous with the pars ciliaris retinae.

Structure of the iris. The iris is composed of four layers, the endothelial layer, connective tissue stroma, a layer of muscular tissue and pigments.

Endothelial layer. It reaches the anterior aspect of the iris from the back of the posterior elastic lamina of the cornea.

Connective tissue stroma. It consists of circular and radial connective tissue fibres which support the blood vessels and nerves of the iris.

Muscular tissue. The muscular tissue consists of unstriped muscle fibres which are arranged into circular and radiating fibres. The circular fibres form a ring round the pupil and are known as the sphincter pupillae. The radiating fibres converge towards the pupillary margin from its circumferential margin and blend with the circular fibres. They are called the dilator pupillae.

The pigments of the iris are variable in different individuals and may be present either in the connective tissue stroma or in the posterior epithelial layers or in both.

Vascular supply of the iris. The arteries supplying the iris are derived from the long and the anterior ciliary arteries.

The *veins* of the iris are corresponding to the arteries and they open into the sinus venosus sclerae.

Nerve supply. The sensory nerves for the iris are the long ciliary branches of the nasociliary. The sphincter pupillae is supplied by the oculomotor nerve (parasympathetic) while the dilator pupillae is supplied by the sympathetic nerves through ciliary ganglion which receives the pre-ganglionic fibres from the first or the second thoracic sympathetic ganglion.

THE REFRACTING MEDIA OF THE EYE

The refracting media of the eye consists of the aqueous humour, the vetreous body and the lens.

Aqueous humour. It is an alkaline fluid derived from the blood plasma and is secreted into the posterior chamber by the ciliary processes. It fills up the posterior and anterior chambers and escapes into the anterior ciliary vein opposite the iridocorneal angle through *the sinus venosus sclerae.*

Vetreous body. It forms a jelly-like substance which is enclosed by a thin membrane known as the hyloid membrane and fills up the concavity of the retina. Anteriorly, it presents a shallow depression—the hyloid fossa in which the lens is received. The hyloid canal passes forwards from the entrance of the optic nerve through the substance of the vetreous body to the posterior surface of the lens. It contains some lymph and some loose areolar tissues. In early embryonic life this was the passage for the hyloid artery which arises from the central artery to the retina. Anteriorly, opposite the ora serrata, the hyloid membrane is thickened and is termed the zonula ciliaris. The zonula ciliaris splits up into two layers, one covering the hyloid fossa and the other, which is thicker in consistency, passes over the ciliary body and is attached to the capsule of the lens. This part of the zonula ciliaris forms the suspensory ligament of the lens.

No vascular structure passes through the vetreous body and its nutrition being maintained by the adjacent blood vessels surrounding it, i.e., vessels from the retina the ciliary processes.

The lens. *It is a solid circular transparent structure embedded in the hyloid* fossa and is interposed between it and the iris. It is convex on all sides but the anterior curvature is less marked than its posterior one. It is covered by a transparent structureless membrane known as the lens capsule. Anteriorly, it is in contact with the margin of the iris and posteriorly lies in contact with the hyloid fossa. The central point of its anterior and posterior curvatures are called the anterior and posterior poles respectively. A line joining these two poles constitutes the axis of the lens. The circumferential margin of the lens is called the equator of the lens.

The lens is kept in position by the suspensory ligament of the lens derived from the hyloid membrane.

The nervous tunic. It consists of retina with its different layers. The optic nerve spreads out into a thin membrane which again consists of different layers and constitutes the formation of the retina. Its outer surface is in contact with the choroid and its inner surface with the hyloid membrane of the vetreous body. Posteriorly, it is continuous with the optic nerve and anteriorly it becomes very thin towards the ciliary body and presents a jagged appearance known as the ora serrata. In the region of the ora serrata the nervous tissue is actually wanting and only it is represented by the membranous prolongation which extends forwards over the ciliary processes and iris and constitutes the ciliary and iridial parts of the retina.

Near the centre of the posterior part of the retina is an oval yellowish area, the macula lutea, *where the visual reception is most perfect.* In the macular area there is a central depression, the favea centralis, where it is very thin. Medial to the macula lutea is the entrance of the optic nerve which forms the optic disc. The centre of the optic disc is pierced by the central artery and vein of the retina. The optic disc is insensitive to light and is termed the blind spot.

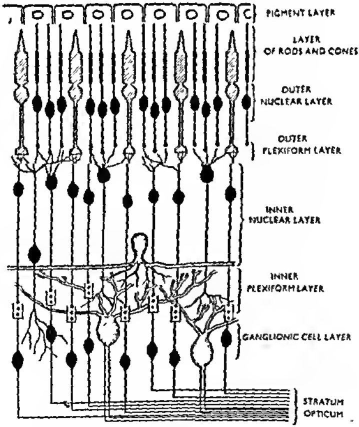

Fig. 890. The constituent layers of the retina.

Structurally, the retina consists of the following layers from without inwards.

(1) Layers of rods and cones.
(2) Outer nuclear layer.
(3) Outer plexiform layer.
(4) Inner nuclear layer.
(5) Inner plexiform layer.
(6) Ganglionic layer.
(7) Stratum opticum.

THE LACRIMAL APPARATUS

The lacrimal apparatus consists of the lacrimal gland, the lacrimal canaliculi, the lacrimal sac, and the nasolacrimal duct.

The lacrimal gland. It is a (serous) compound tubulo-alveolar gland resembling salivary gland in structure and forms the secretory part of the lacrimal apparatus. It secretes an alkaline fluid, the tears, which among other things, contain a bactericidal enzyyme known as lysozyme and is concerned in protecting the eye against drying and infection.

Situation. It is situated mainly, in the lacrimal fossa formed by the depressed area on the medial aspect of the zygomatic process of the frontal bone, and partly, over the root of the upper eyelid where it flows out of the lacrimal fossa as the palpebral process.

Shape and size. It is irregular in shape, and in size, it resembles like that of an almond.

Parts for examination. It consists of a *main or orbital portion* and a *palpebral process* and about three to nine small ducts. The main portion is contained within the lacrimal fossa whereas the palpebral process extends over the root of the upper eyelid. The two portions of the gland are continuous with each other around the free posterior border of lateral horn of the aponeurosis of the levator palpebrae superioris by a narrow isthmus.

Stability of the gland. The gland is supported and maintained in position by the aponeurosis of the levator palpebrae superioris. The superior aspect of the lateral rectus also supports it from below. The periorbita (orbital periosteum) sends out septa within the gland which form additional supports for the gland.

Relations. *Laterally* the orbital portion is direct contact with the medial aspect of the zygomatic process of the frontal bone in the lacrimal fossa, medially it is in relation with the lateral aspect of the eyeball, anteriorly, it is in relation with the orbital septum which separates it from the structures of the upper eyelid. The palpebral portion extends into the lateral part of the upper eyelid around free posterior borders of the aponeurosis of the levator palpebrae superioris and intervenes between the conjunctiva below and the aponeurosis of the levator palpebrae superioris above.

Lacrimal ducts. There are about 3 to 9 small ducts which open into the lateral part of the superior conjunctival fornix.

Vascular supply. The arteries supplying the lacrimal gland are the lacrimal branch of the ophthalmic artery and a branch from the infraorbital artery. The veins from the gland drain into the ophthalmic vein.

Lymphatics. The lymphatics draining the lacrimal gland join with the conjunctival lymphatics and finally drain into the preauricular lymph node.

Nerve supply. The lacrimal gland is supplied by sensory, secretomotor or parasympathetic and sympathetic nerves. The lacrimal branch of the ophthalmic nerve is the sensory nerve for the lacrimal gland.

Secretomotor. It receives postganglionic fibres from the pterygopalatine (sphenopalatine) ganglion which pass through the maxillary nerve, its zygomaticotemporal branch, the communicating branch of the latter with the lacrimal nerve, and the lacrimal nerve. Its preganglionic fibres are derived from the superior salivary nucleus of the facial nerve and then pass through the same nerve and its geniculate ganglion and its greater (superficial) petrosal branch to reach the pterygopalatine (sphenopalatine) ganglion where they end by synapse.

The gland is also supplied by *sympathetic filaments.*

Development. The ectodermal epithelium lining the lateral part of the superior conjunctival fornix in the conjunctival sac is evaginated to form epithelial buds which later on develop into acinous glands, the lacrimal gland and its ducts.

The **lacrimal sac** forms the reservoir of the tears and is placed in a fossa formed by the lacrimal bone, frontal process of the maxilla and the lacrimal fascia. It measures about half an inch in length and its upper end forms a flattened blind extremity. Its lower end is rounded and is prolonged downwards into the inferior meatus of the nose as the naso-lacrimal duct through which the lacrimal fluid is carried to the nose.

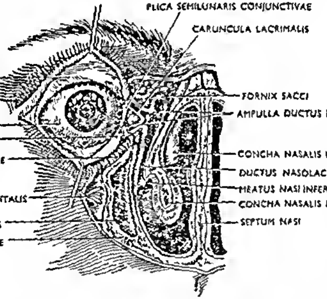

Fig. 891. The anatomy of the lacrimal apparatus. With kind permission from: Callanders Surgical Anatomy, 2nd edition, 1939, W. B. Saunders Company, Philadelphia and London.

Lacrimal canaliculi. These are the tubular passages through which the tears pass to the lacrimal sac. They are two in number, one for each eyelid, and each measuring about 10 mm. in length. Each canaliculus begins at the corresponding puncta lacrimalia and ends by opening ioto the lateral wall of the lacrimal sac. The superior canaliculus is shorter than the inferior one and it at first ascends and then making an acute angle passes downwards and medially to end into the lacrimal sac. The inferior canaliculus passes at first downwards and then runs horizontally to end into the lacrimal sac.

Development of the optic nerve and visual apparatus. The visual apparatus develops from surface ectoderm, neural ectoderm (ectoderm giving origin to neural plate) and from the mesoderm.

The anterior end of the neural plate in early somite stage forms bilateral thickenings which form the optic primodia. With the closure of the anterior neuropore the

optic primodia appear as bilateral diverticula of the forebrain or prosencephalon and they are called the optic vesicles.

Optic vesicles. Each optic vesicle appears as a diverticulum of the forebrain and contains a cavity within, which is continuous with the cavity of the forebrain. Then the vesicle elongates and forms a constricted proximal portion called the optic stalk and an expanded distal portion. The expanded distal portion soon comes into contact with the surface ectoderm which soon becomes thickened to form the lens placode. At about 5 mm. stage, the lens placode is depressed and sinks below the level of the surrounding ectoderm. With gradual depression it is converted into a vesicle, the lens vesicle, which soon becomes separated from the surrounding ectoderm. Concurrently with the formation of the lens vesicle, the distal portion of the optic vesicle is invaginated into its proximal portion and forms a cup-like depression known as the optic cup which now consists of an outer and an inner layer of neural ectoderm. The optic cup is deficient inferiorly due to the presence of the foetal fissure through which blood vessels pass to the posterior aspect of the lens vesicle. The foetal fissure then gradually becomes narrowed by the growth of its margin and at about 11 mm. stage its margin opposite the intermediate portion has fused around the blood vessels and from this point gradual fusion extends both proximally and distally and the fissure is completely obliterated at about 15 mm. stage. Incomplete fusion or absence of fusion results in a condition of developmental error known as coloboma.

The cells of the outer layer of the optic cup soon acquire pigments, and later form the pigmented layer of retina. The cells of the inner layer then proliferate proximally and occlude the cavity of the optic vesicle and come to lie in contact with the pigmented layer. Later on, the cells of the inner layer of the optic cup differentiate into anterior and posterior layers which are continuous with each other at the periphery. From the thickened posterior layer the pars optica retinae is formed while the thin anterior portion is called the pars caeca retinae. The junction between pars optica retinae (visual receptor) and the pars caeca is marked by the ora serrata. The pars caeca then splits up into anterior and posterior portions. The anterior portion extends forwards over the developing lens and forms the pars iridis retinae while the posterior portion forms the pars ciliaris retinae. The pars iridis retinae later on forms the posterior layer of the definitive iris. The pars optica retinae later forms the other layers of retina and the axons of the innermost layer form the optic nerve which passes backwards through the optic stalk and obliterates its lumen. The spongioblasts of the optic stalk later on form the glial elements in this region.

Lens. The lens vesicle during 10 mm. stage forms a hollow spherical body consisting of a single layer of columnar cells. Later on, the cells of the two walls of the lens vesicle show differential character and proliferate rapidly. The cells of the anterior wall become cuboidal and they form the anterior epithelial lens capsule. The cells of the deep or posterior wall grow rapidly and obliterate the cavity of the lens vesicle and they form the whole of the lens proper except the anterior epithelial lens capsule. The elongated cells of the posterior layer are arranged in layers which soon lose the nuclei and form the lens fibre and make it laminated. The lens capsule is vascularised posteriorly through the hyloid artery which reaches it through the foetal fissure while its anterior part is vascularised by the annular artery. In normal cases these vessels undergo retrogression before birth but very rarely they persist in some form of congenital cataract and also in cases where the pupillary membrane persists.

Vetreous body. The space between the posterior surface of the developing lens and the concavity of the optic cup is occupied by a reticulated jelly-like substance which forms the primodia of the hyloid or vetreous body. The hyloid vessels which pass through the foetal fissure run through the hyloid body before reaching the lens capsule. The hyloid body is surrounded by a membrane called the hyloid membrane. It develops from mesoderm (?)

Cornea, sclera and choroid. After the separation of the lens vesicle from the surface epithelium the underlying mesoderm extends forwards and intervenes between the lens and the surface ectoderm and they together form the cornea. The ectoderm forms the anterior epithelial covering of the cornea while the rest of it develops from the mesoderm. The mesodermal condensation around the optic cup separates into an inner and an outer layer. The inner layer forms the choroid which is vascular layer while the outer one forms the sclera which is continuous anteriorly with the cornea at the sclero-corneal junction. At first the cornea is opaque like the sclera but later on, histological changes supervene which transforms it into a transparent layer. The choroidal layer becomes much thicker opposite the margins of the optic cup and forms the ciliary body.

Iris and aqueous chambers. The iris develops both from the mesoderm and the neural ectoderm. The mesoderm in front of the lens epithelium forms the pupillary membrane and this together with the pars caeca retinae, which passes forwards beyond the lens, forms the iris. At birth the central part of the pupillary membrane breaks down to form the pupil.

The aqueous chamber develops as a cavity in the mesenchyme in front of the lens and is limited in front by the posterior surface of the cornea. The iris which soon develops and projects into it, subdivides it into anterior and posterior chambers which communicate with each other through the pupil.

Eye lids, conjunctiva and the lacrimal apparatus. The eye lids develop both from the ectoderm and mesoderm and appear as two folds, one above the cornea and one below it. The margins of the folds grow rapidly and soon meet each other and then undergo epithelial fusion and thus enclosing a space the conjunctival sac.

The lacrimal gland appears as solid epithelial buds at the outer part of the conjunctival sac, and later on, these buds develop into acinous glands and their ductules open into the conjunctival sac. The lacrimal canaliculi develop as solid epithelial buds which are situated at the medial end of each eye lid margin. The two canaliculi develop and grow medially and fuse independently with another solid epithelial bud situated at the line of junction between the maxillary and lateral nasal processes. They later on form the lacrimal sac and the naso-lacrimal duct which opens into the inferior meatus of the nose.

THE EAR

The ear or the organ of hearing is divisible into three parts and from without inwards these parts are the external ear, middle ear or tympanic cavity and the internal ear or the labyrinth.

THE EXTERNAL EAR

The external ear consists of a large expanded portion known as the *auricle* which acts as a receiver of sound and then conducts it through a narrow canal known as the *external acoustic (auditory) meatus* to the tympanic membrane.

The auricle is irregularly oval in form and is broader above than below. Its lateral surface is irregularly concave whereas its cranial surface is unevenly convex. It consists of a single plate of cartilage which is irregularly bent on itself so as to produce numerous eminences and depressions on its lateral surface. The prominent rim of the auricle is known as the *helix*. In front of the helix and separated from it by a curved hollow the rim-like eminence is known as the *antihelix*. The antihelix bifurcates above to enclose a triangular depression known as the *triangular fossa*. The *scaphoid fossa* lies in between the upper border of the triangular fossa and the

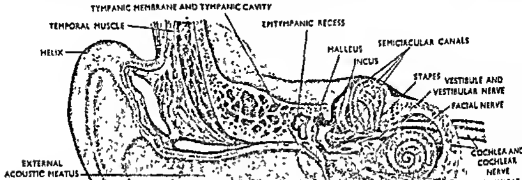

Fig. 892. The anatomy of the ear. With kind permission from: Lederle Laboratories Ltd. Drawn by Mr. Paul Peck.

helix. The deep depression in front of the antihelix is formed by the *concha*. The antihelix ends below into a conical projection known as the *antitragus*. The conical projection in front of the concha is known as the *tragus*. The notch in between the tragus and the antitragus is known as the *intertragic notch*. The lobule of the ear hangs downwards from the lower end of the helix and antihelix. It is devoid of any cartilage.

The *external acoustic meatus* is a narrow cylindrical passage consisting of a cartilaginous and a bony part. The *cartilaginous part* is about 1/3 inch in length and joins

the bony part at a constriction known as the *isthmus.* The *bony part* is formed by the tympanic part of the temporal bone and measures about 2/3 inch in length. It is directed downwards, forwards and medially. The whole of the external acoustic meatus together with the external surface of the tympanic membrane is lined by skin. The skin of the external acoustic meatus contains numerous seruminous glands which secrete the ear-wax.

THE MIDDLE EAR OR THE TYMPANIC CAVITY

The tympanic cavity is a laterally compressed vertical recess within the petrous part of the temporal bone and is interposed between the bottom of the external acoustic meatus and the internal ear or the labyrinth.

In consists of a roof, a floor, a posterior, an anterior, a medial and a lateral wall.

As it is compressed on either side the tympanic cavity is smallest in its transverse diameter and measures about 1/12 to 1/6 inch from its lateral to its medial wall. Its vertical and antero-posterior diameters measure about 1/2 an inch in length.

The **roof of the tympanic cavity is** formed by a thin plate of bone known as the tegmen tympani which separates it from the middle cranial fossa.

The floor or the jugular wall is narrow and is formed by a *thin osseous lamina* which separates it from the jugular fossa which contains the superior bulb of the internal jugular vein. Its lower part lies below the level of the tympanic membrane and the auditory (pharyngotympanic) tube.

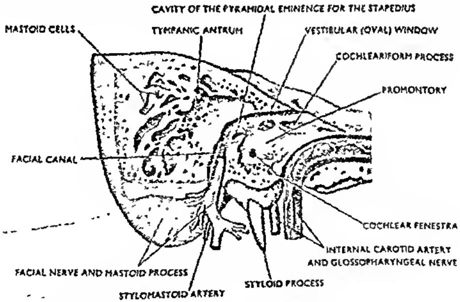

Fig. 893. The anatomy of the middle ear. With kind permission from: Lederle Laboratories Ltd. Drawn by Mr. Paul Peck.

The posterior or mastoid wall *is formed above* by the epitympanic recess which communicates it with the tympanic antrum, and below that, by a conical hollow projection known as the pyramid. Into the hollow of the pyramid there lies the stapedeus muscle.

The **anterior wall** is narrow because the medial and the lateral walls converge anteriorly. The upper part of the anterior wall is formed by the opening for the tensor tympani muscle, the intermediate part by the tympanic opening of the auditory tube and the lowest part is formed by a thin osseous lamina which separates the tympanic cavity from the carotid canal.

The **medial wall of the tympanic cavity** is formed by the internal ear and it presents the following features.

(*a*) *Promontory*. It is a small rounded bony prominence in the anterior part of the medial wall and is formed by the first turn of the cochlea. Its surface presents numerous delicate furrows for the lodgement of the tympanic plexus of nerves.

(*b*) *Fenestra vestibuli*. It is an oval opening situated above and behind the promontory. In the recent state the base of the stapes fits into it and is anchored by the annular ligament.

(*c*) *Fenestra cochleae*. It is a small opening situated below and behind the fenestra vestibuli and is hidden by the posterior part of the promontory. It opens into the scala tympani of the cochlea and is closed up by the secondary tympanic membrane in the recent state.

(*d*) *Prominence of the facial canal*. It is an anteroposterior bony prominence on the medial wall of the tympanic cavity which begins immediately above the fenestra vestibuli and passes backwards to the medial wall of the epitympanic recess from where it descends downwards on the posterior wall of the tympanic cavity. In the recent state it lodges the facial nerve.

The **lateral wall** of the tympanic cavity is formed by the tympanic membrane, tympanic ring and by a portion of the squamous part of the temporal bone above the tympanic membrane.

Contents — ① Air.

Arteries:

(1) Anterior tympanic branch of the maxillary artery.
(2) Stylomastoid branch of the posterior auricular artery.
(3) Superficial petrosal branch of the middle meningeal artery.
(4) Superior tympanic branch of the middle meningeal artery.
(5) Tympanic branch of the ascending pharyngeal artery.
(6) Tympanic branch of the internal carotid artery.

Veins. The veins of the tympanic cavity end into the pterygoid venous plexus and into the superior petrosal sinus.

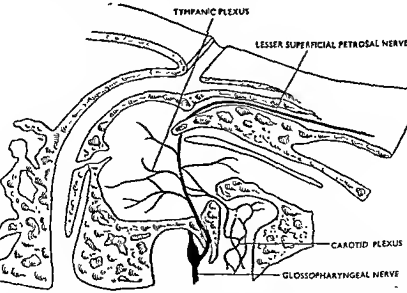

Fig. 694. The tympanic plexus of nerves in the middle ear. With kind permission from Prof W. Hollinshead Ph.D. Anatomy for the Surgeons, Vol. I Paul B. Hoeber INC.

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(1) Tympanic branch of the glossopharyngeal nerve.
(2) Superior and inferior caroticotympanic nerves from the carotid plex of sympathetic.
(3) Chorda tympani branch of the facial nerve.

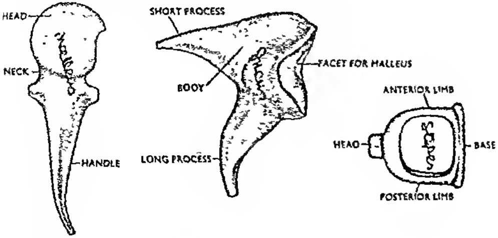

Fig. 895. The auditory ossicles.

Muscles

(1) Stapedeus.
(2) Tensor tympani muscle.

Bones

(1) Malleus.
(2) Incus.
(3) Stapes.

Ligaments

(1) Anterior, lateral and superior ligaments of the malleus.
(2) Posterior and superior ligaments of the incus.
(3) Annular ligament of the stapes.

The tympanic cavity is lined by mucous membrane derived from the pharyngotympanic tube. It is supplied by the arteries contained in the cavity and its nerve supply is derived from the tympanic plexus formed by the tympanic branch of the glossopharyngeal nerve and the superior and inferior caroticotympanic nerves from the carotid plexus of sympathetics.

The tympanic membrane. The tympanic membrane or the drum of the ear is an oval trilamellar membrane which is interposed between the bottom of the external acoustic meatus and the middle ear or the tympanic cavity and is the receiver and transmiter of the sound vibrations from the external to the middle ear.

Measurements. Its long axis is nearly vertical and measures about 10 mm. and its shortest diameter varies between 8 and 9 mm. and about ·5 mm. in thickness.

Position. It is oblique in position being directed forwards and medially from the postero-superior to the antero-inferior wall of the external acoustic meatus. In its position it maintains an angle of 55 degrees with the bottom of external acoustic meatus.

Form, Colour and transparency. It is oval in form being broader above than below and is a greyish semitransparent membrane.

Attachment. The cercumferential margin of the tympanic membrane forms a thickened, fibrocartilaginous rim which is attached to the tympanic sulcus, formed by the tympanic part of the temporal bone at the bottom of the bony external acoustic meatus, except superiorly where the tympanic sulcus is deficient and the membrane is attached to the squamous part of the temporal bone.

Descriptive parts. The tympanic membrane presents for examination a *circumferential margin*, which is attached to the bone as described above, and a *medial* and a *lateral surface*.

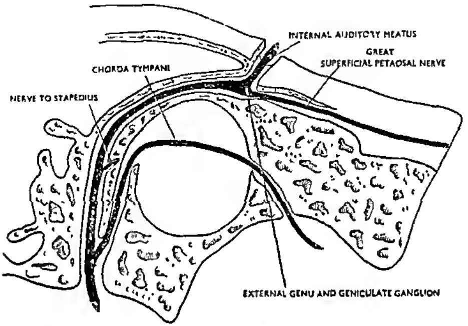

Fig. 896. The intra-petrous part of the facial nerve. With kind permission from: Prof. W. H. Hollinshead Ph.D., Anatomy for the Surgeon, Vol. I. Paul B. Hoeber INC.

Its *lateral surface* forms the medial boundary of the external acoustic meatus and is gently concave so as to form a receiving surface for the sound waves. This surface is lined by the skin of the external ear.

Its *medial surface* is lined by the mucous membrane of the middle ear cavity and forms the lateral boundary of the latter. This surface is convex and the maximum convexity corresponds to the attachment of the tip of the manubrium of the malleus to it and coincides with a point which lies just below and posterior to its centre. This point of maximum convexity on the medial surface is called the *umbo*.

The distance between the medial surface of the tympanic membrane and the medial wall of the tympanic cavity varies between 2 and 4 mm. and thus its antero-superior quadrant is closely related to the tympanic opening of the auditory tube; when the thin lamina of bone separating the carotid canal from the tympanic cavity is deficient its antero-inferior quadrant comes into relation with the internal carotid artery; its postero-superior quadrant is related to the stapes, oval window and the long process of the incus while its postero-inferior quadrant is related to the promontory.

Two mucous folds, *anterior* and *posterior malleolar folds* extend to the two ends of the tympanic sulcus from the lateral process of the malleus. The portion of the tympanic membrane enclosed between the malleolar folds is called the *pars flaccida* and the rest of the tympanic membrane is known as the *pars tensa*. As the name implies the pars flaccida is loose and lax whereas the pars tensa is stretched and tense due to attachment of the manubrium of the malleus and the tensor tympani muscle into the latter.

Structures within the membrane. The handle of the malleus and its lateral process is engrafted within the tympanic membrane being interposed between its inner mucous lining and the intermediate fibrous layer and extends roughly half-way downwards into it. The chorda tympani nerve enters the tympanic cavity through its posterior wall through the posterior canaliculus for the chorda tympani nerve and traverses through the tympanic membrane anteroposteriorly between the fibrous and mucous layers and passes across the handle of the malleus and emerges out of it by passing through the anterior canaliculus for the chorda tympani nerve at the inner end of the petrotympanic fissure.

Otoscopic view of the tympanic membrane. In an otoscope, when light falls on the tympanic membrane, the latter appears to be greyish in colour. A prominent spot on the antero-superior sector adjoining the circumferential margin is due to the lateral process of the malleus, and projecting downwards and backwards up to the umbo is a ridge caused by the handle of the malleus. The membrane can be divided into four quadrants, antero-superior, antero-inferior, postero-superior and postero-inferior, by two lines, one vertical corresponding to the line of the handle of the malleus, and the other horizontal crossing at a right angle to the former line opposite the tip of the handle of the malleus. When light falls on the membrane a bright area called the "cone of light" radiates downwards and forwards from the tip of the handle of the malleus in the antero-inferior sector of the membrane. Superiorly the anterior and the posterior malleolar folds are seen to extend to the periphery in a V-shaped manner, the apex of "V" corresponding with the lateral process of the malleus.

Histological structure. Histologically the tympanic membrane consists of outer cuticular, intermediate fibrous and inner mucous layer.

The *outer cuticular layer* is continuous with the skin of the external acoustic meatus and is covered by stratified epithelium.

The *intermediate fibrous layer* consists of radiating and circular fibres. The radiating fibres radiate from the handle of the malleus superficially while the circular fibres lie deep to them and are found to be scattered in the centre while they condense towards the periphery of the membrane. The intermediate fibrous layer is deficient in the pars flaccida which, therefore, consists of two layers, outer cuticular and inner mucous layer.

The *inner mucous layer* is continuous with the mucous lining of the middle ear and is covered by the columnar ciliated epithelium.

Vascular supply. Its outer cuticular layer is supplied by the *deep auricular branch of the maxillary artery* and its inner layer is supplied by the *stylomastoid branch of the posterior auricular artery* and by the *tympanic branch of the maxillary artery.*

The *veins* draining its outer surface open into the external jugular vein and its inner surface is drained by veins which open either into transverse sinus or into the veins of the dura mater and communicate with the plexus of veins on the (pharyngo-tympanic) auditory tube.

Lymphatics. The lymphatics follow the blood vessels and terminate into upper deep cervical group of lymph nodes.

Nerve supply. Its outer surface is supplied by the auriculotemporal nerve and the auricular branch of the vagus nerve and its inner surface is supplied by the tympanic branch of the glossopharyngeal nerve through the tympanic plexus.

Development. Developmentally the tympanic membrane is a composite structure being formed by the three germinal layers, ectoderm, entoderm and the mesoderm.

The inner mucous layer is formed by the entoderm of the tubotympanic recess which is an entodermal diverticulum from the first and the second phanyngeal pouches. The outer cuticular layer is derived from the ectoderm lining the first branchial cleft which forms the auditory pit. The cells of the bottom of the cleft proliferate to form a mass of cells known as the *meatal plate* which grows inwards towards the distal end of the tubotympanic recess, which is destined to form the tympanic cavity. During late foetal life, the central cells of the meatal plate break

Attachment. The circumferential margin of the tympanic membrane forms a thickened, fibrocartilaginous rim which is attached to the tympanic sulcus, formed by the tympanic part of the temporal bone at the bottom of the bony external acoustic meatus, except superiorly where the tympanic sulcus is deficient and the membrane is attached to the squamous part of the temporal bone.

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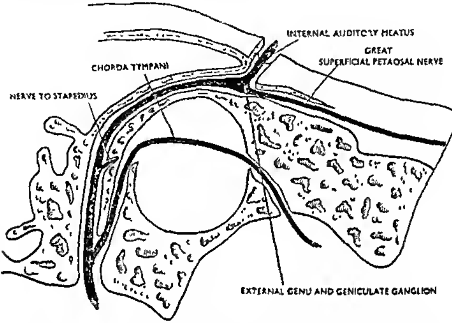

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Vascular supply. Its outer cuticular layer is supplied by the *deep auricular branch of the maxillary artery* and its inner layer is supplied by the *stylomastoid branch of the posterior auricular artery* and by the *tympanic branch of the maxillary artery*.

The *veins* draining its outer surface open into the external jugular vein and its inner surface is drained by veins which open either into transverse sinus or into the veins of the dura mater and communicate with the plexus of veins on the (pharyngotympanic) auditory tube.

Lymphatics. The lymphatics follow the blood vessels and terminate into upper deep cervical group of lymph nodes.

Nerve supply. Its outer surface is supplied by the auriculotemporal nerve and the auricular branch of the vagus nerve and its inner surface is supplied by the tympanic branch of the glossopharyngeal nerve through the tympanic plexus.

Development. Developmentally the tympanic membrane is a composite structure being formed by the three germinal layers, ectoderm, entoderm and the mesoderm.

The inner mucous layer is formed by the entoderm of the tubotympanic recess which is an entodermal diverticulum from the first and the second phanyngeal pouches. The outer cuticular layer is derived from the ectoderm lining the first branchial cleft which forms the auditory pit. The cells of the bottom of the cleft proliferate to form a mass of cells known as the *meatal plate* which grows inwards towards the distal end of the tubotympanic recess, which is destined to form the tympanic cavity. During late foetal life, the central cells of the meatal plate break

down to form the deeper part of the external acoustic meatus and the deepest layer of cells forms the cuticular layer of the tympanic membrane. The intervening mesoderm, in which the handle of the malleus also grows, forms the fibrous element of the membrane.

Applied Anatomy. Retraction of tympanic membrane may occur due to blockage of the auditory tube and absorption of the air contained in the middle ear. Myringotomy is done through the postero-inferior sector of the tympanic membrane to avoid injury to the chorda tympani nerve.

The tympanic antrum. The tympanic antrum is a recess or air chamber situated partly within the petrous and partly within the mastoid part of the temporal bone. It lies immediately below and behind the epitympanic recess of the tympanic cavity and occupies the deploic layer at the expense of the bone marrow. Together with the epitympanic recess it resembles a retort in shape and the bowl of the retort represents the tympanic antrum and its elongated neck, the epitympanic recess.

Boundary. Its **roof** is formed by a thin plate of bone known as the tegmen tympani which separates it from the posterior part of the middle cranial fossa which is closely related to the sigmoid sinus. Its **floor** is formed by the mastoid air cells. **Medially** it is bounded by the lateral semicircular canal and by the prominence of the facial canal. **Laterally** it is bounded by that portion of the squamous part of the temporal bone which lies below the supramastoid crest. **Anteriorly** it is bounded, above, by the epitympanic recess, and below, by a thin plate of bone which separates it from the inner part of the external acoustic meatus. **Posteriorly** it is formed by the mastoid air cells and is separated from the cerebellum and the transverse sinus by a thin plate of bone. The tympanic antrum is slightly smaller than the tympanic cavity and is lined by the same mucous membrane which lines the tympanic cavity. The tympanic antrum is comparatively large at birth when still the mastoid air cells begin to sprout from the antrum and grow like a racemose gland.

The tympanic antrum contains air and the source of the air into it is from the tympanic cavity which in turn derives the air from the nasal part of the pharynx through the auditory (pharyngotympanic) tube.

Communications. Anteriorly it communicates with the tympanic cavity through the epitympanic recess and through the tympanic cavity and the auditory (pharyngotympanic) tube with the nasal part of the pharynx. Posteriorly it communicates with the mastoid air cells.

Difference between the mastoid air cells and para-nasal sinuses.

	Paranasal sinuses	Mastoid air cells
Origin	All paranasal sinuses arise independently within the respective bones except the frontal air sinuses which develop from the anterior ethmoidal air cells.	The mastoid air cells sprout from the tympanic antrum.
Shape	Each assumes some geometrical shape.	They resemble compound racemose gland and the cells branch out from a common stem.
Mucous lining	Covered by muco-periosteum which contains some mucous glands.	Covered only by mucous membranes derived from the tympanic cavity and the tympanic antrum and the mucous glands are absent.

Vascular supply. The stylomastoid branch of the posterior auricular artery pplies the tympanic antrum. The veins of the tympanic antrum open into the erygoid venous plexus and into the superior petrosal sinus.

Nerve supply. The mucous membrane of the tympanic antrum is supplied y the tympanic plexus formed by the tympanic branch of the glossopharyngeal erve and the superior and inferior caroticotympanic nerves from the carotid plexus f sympathetics.

Surgical importance. Inflammatory processes starting in the tympanic antrum may spread towards its different walls causing variety of clinical manifestations such as meningitis, brain abscess, sigmoid sinus thrombosis, perforation of the mastoid process, etc.

THE INTERNAL EAR

The internal ear is concerned with the perception of sounds and maintenance of equilibrium. It consists of a bony labyrinth and a membranous labyrinth.

The bony labyrinth consists of three parts, the cochlea, the vestibule and the semicircular canals. All of them are embedded within the petrous part of the temporal bone medial to the tympanic cavity and the whole apparatus measures about 3/4 of an inch in length.

The cochlea resembles a snail's shell with two and a half coils. It consists of a central pillar, the modiolus, around which two and a half turns of osseous spiral lamina, like that of a thread of a screw, project within the bony tube. The osseous spiral lamina only extends half way within the cochlear canal (the bony tube) and from free its margin it gives attachment to a membrane, the *basilar membrane* which together with the osseous lamina completely subdivides the cochlear canal into two

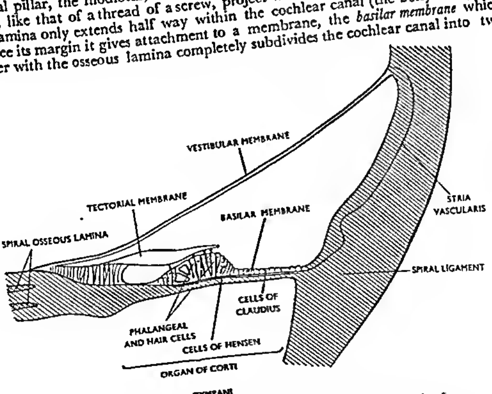

Fig. 897. The organ of corti of the internal ear. With kind permission from: Prof. W. H. Hollinshead Ph.D., Anatomy for the Surgeons, Vol. I. Paul B. Hoeber INC.

compartments, the *scala vestibuli* above and the *scala tympani* below. A more delicat membrane, the *vestibular membrane*, projects from the base of the osseous spiral lamir

to be attached to the bony wall of the cochlea a little above the attachment of the basilar membrane. The scala vestibuli opens into the vestibule while the scala tympani is separated from the tympanic cavity, at the fenestra cochlea by the *secondary tympanic membrane.* The two scalae are continuous with each other at the apex of the cochlea by an opening called the *helicotrema.* A small duct, the *aqueduct of the cochlea* traverses a small bony canal in the petrous portion of the temporal

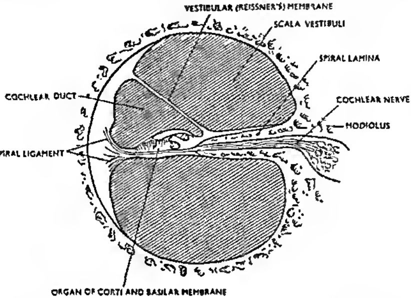

Fig. 898. The anatomy of the cochlea of the internal ear. With kind permission from: Prof W. H. Hollinshead, Anatomy for the Surgeons, Vol. I. Paul B. Hoeber INC.

bone, the summit of which opens at the apex of the triangular depression situated immediately below the internal acoustic meatus on the inferior surface of the petrous part of the temporal bone. It communicates with the subarachnoid space and it is through this aqueduct that the cerebrospinal fluid comes into the cochlea and constitutes the perilymph of the bony labyrinth.

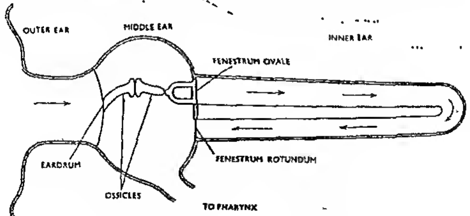

Fig. 899. The hearing mechanism. (Diagrammatic)

The **vestibule** communicates in front with the cochlea and behind with the three semicircular canals. Medially it communicates with the posterior cranial fossa by the aqueduct of the vestibule. By the fenestra vestibuli it communicates

with the tympanic cavity. The base of the stapes is attached to the fenestra vestibuli (oval window).

The **semicircular canals** are three in number. The superior, posterior and the lateral semicircular canals. They are placed at right angle to each other and occupy three planes in space. All of them communicate with the vestibule by their two ends and near their termination each presents a dilatation known as the *ampulla* of the semicircular canal. At one end the superior and the posterior semicircular canals open into the vestibule by a common stem, the *crus commune* and hence they open into the vestibule by five openings instead of six. The *superior semicircular canal* produces an eminence, the *arcuate eminence* on the anterior surface of the petrous portion of the temporal bone. The *lateral semicircular* canal also causes an elevation on the medial wall of the tympanic cavity and the epitympanic recess.

The **membranous labyrinth** consists of a *cochlear duct*, the *saccule* and the *utricle* and the three *semicircular ducts*. It is a closed system and contains some fluid within known as the *endolymph*. A recess of the membranous labyrinth projects from the saccule and the utricle through a minute canal which opens into a slit-like opening at the posterior part of the internal acoustic meatus and is known as the *ductus endolymphaticus*. It is the safety valve of the membranous labyrinth and prevents excessive shock in the endolymph. The cochlear duct lies on the vestibular side of the basilar membrane and is enclosed between the basilar membrane and the vestibular membrane, and communicates with the saccule by a narrow canal, the *canalis reuniens*. The saccule and the utricle are contained within the vestibule and they communicate with each other by a 'Y'-shaped duct, the *ductus utriculosaccularis*. The limbs of the 'Y' join the utricle on one side and the saccule on the other side and the stem of the 'Y' is prolonged as a diverticulum, the *succus endolymphaticus* which passes through the aqueduct of the vestibule in the posterior surface of the temporal bone. The semicircular ducts occupy the semicircular canals and open into the utricle.

Vessels and nerves. The internal auditory artery, a branch of the posterior cerebellar artery or basilar artery, enters through the internal acoustic meatus and supplies the internal ear. The veins open into the inferior petrosal sinus. The cochlear branch of the stato-acoustic nerve is the nerve of hearing and is distributed to the cochlea, and the vestibular branch of the stato-acoustic nerve is the nerve of equilibrium which is distributed to the semicircular canals, the utricle and the saccule.

Development of the auditory apparatus. The internal ear arises from an ectodermal thickening, the *otic placode* which lies on each side of the developing hind-brain during seventh somite stage of the growing embryo. During later development, the ectoderm surrounding the otic placode becomes elevated due to proliferation of the underlying mesoderm. Consequent upon the elevation of the surrounding ectoderm, the otic placode now is a depression known as the *otic pit*. A about 30 somite stage the otic pit forms a vesicle, the *otic vesicle* or the *otocyst*. The otocyst at this stage is related anteromedially to the acoustico-facial portion of the neural crest which is invaded by some of its cells. The neuroblasts collected in the acoustico-facial portion of the neural crest form the primodia of the acoustico-facial ganglion. The cells of the acoustic ganglion are bipolar and remain so throughout the rest of the life. The peripheral processes of the bipolar cells are distributed to the otocyst which, later on, develops into specialized sensory organs. Their central processes grow in the region of the rhombic lip and later on differentiate into vestibular and cochlear nerves. Later on, a diverticulum appears from the medial wall of the otocyst and then becomes elongated to form the endolymphatic sac.

The otocyst then shows differential growth and becomes constricted in its middle part and is divided into an upper vestibular pouch and a lower cochlear pouch. From the upper part of the vestibular pouch the three semicircular canals are formed while its lower part forms the utricle into which the semicircular canals open. The

cochlear pouch soon differentiates into an upper and a lower part. The upper part forms the saccule while its lower part rapidly elongates and then becomes coiled to form the cochlea.

The mesenchyme round the derivatives of the otocyst soon becomes condensed and later on becomes chondrified to form the otic cartilages. The otic cartilages again become differentiated to form loose periotic tissue from which later on the bony framework of the internal ear is formed.

The middle ear or the tympanic cavity has different history of origin. Together with the pharyngo-tympanic tube it develops as tubo-tympanic recess from the first pharyngeal pouch and from the adjacent parts of second pouch. The first ectodermal cleft represents in part the external acoustic meatus, and while extending, the tubo-tympanic recess comes in contact with the ectoderm of the first ectodermal cleft and the area of contact between the two, together with the intervening mesoderm, forms the tympanic membrane. Thus it is evident that the outer cuticular layer of the tympanic membrane is derived from ectoderm, the inner mucous layer from endoderm while the intermediate fibrous layer is derived from the mesoderm.

The first (Meckel's) and the second (Reichart's) arch cartilages lie in the branchial mesoderm both in front of and behind the tubo-tympanic recess. From the first arch cartilages the incus and the malleus are formed while the stapes is formed from the second arch cartilage. The tensor tympani muscle is associated with the malleus while the stapedeus is in association with the stapes and they arise from the branchial arch mesoderm. They receive their nerves from the nerve of the first and the second arches respectively, i.e., the tensor tympani from the nerve of the first arch (mandibular) and the stapedeus from the nerve of the second arch (facial).

The EXTERNAL EAR develops from a number of ectodermal hillocks surrounding the opening of the first ectodermal cleft.

THE SURFACE OR THE TOPOGRAPHICAL ANATOMY

Surface anatomy or topographical anatomy deals with the study of the different structures by drawing their general outline on the surface of the body so as to ascertain their exact position in relation to the skin surfaces. With the knowledge of surface anatomy one can well estimate the situation of a particular structure and can explore it from the surface wherever necessary. Bony, muscular and other prominences and natural hollows or grooves on the surface of the body are taken as guides, and the relation of the internal structures with these landmarks are noted and the general outline of the structure is mapped out on the surface by lines.

THE ABDOMEN

Anterior abdominal Wall. The features of the anterior abdominal wall varies greatly with age, sex, adiposity and disease. The rounded contour of the abdomen in children is due to the large size of the liver and the small size of the pelvic cavity. The smaller pelvic cavity cannot accommodate all the organs in it and some of the organs project into the abdominal cavity, which, to some extent, is responsible for its rounded contour. Thus the urinary bladder, which is a pelvic organ in the adult, is an abdomino-pelvic organ in the children.

Linea alba. This corresponds to the median groove on the anterior abdominal wall and extends from the tip of the xiphoid process to the symphysis pubis. The umbilicus forms a median fossa opposite the third and the fourth lumbar vertebrae.

Linea semilunaris. Linea semilunaris corresponds to the lateral border of the rectus abdominis and can be represented by a curved line, concave outwards, drawn from the tip of the ninth costal cartilage to the pubic tubercle.

Umbilicus. The position of the umbilicus greatly varies with obesity and laxity of the abdominal wall and its normal position corresponds to a point 4/5 inches below the midpoint between the xiphoid process and the symphysis pubis and corresponds to the disc between the third and the fourth lumbar vertebrae anteriorly and to the third lumbar spine posteriorly.

Transpyloric plane. Take a point opposite the tip of the corresponding ninth rib and join them by a straight line which will represent the transpyloric plane and this plane cuts the lower border of the body of the 1st lumbar vertebra. It also corresponds to a transverse line drawn across the anterior abdominal wall between the supra-sternal notch and the top of the symphysis pubis. The following important structures can be found opposite this level:

(1) On the right side, opposite the tip of the ninth rib, there lies the fundus of the gall bladder.
(2) It corresponds to the lower border of the first lumbar vertebra.
(3) The hilum of the kidney lies opposite this level about 2½ inches from the median plane.
(4) The superior mesenteric artery arises from the abdominal aorta opposite this level in the median plane.
(5) The pyloric portion of the stomach lies opposite this level in the cadaver, and in supine position during life within 1/2 inch of the mid-line.
(6) The spinal cord ends at the conus medullaris opposite the lower border of the first lumbar vertabra.
(7) The thoracic duct begins at this level.
(8) The tail of the pancreas lies opposite this level.
(9) lower border of Liver (in Male) or female & child it is slightly below

Subcostal plane. It lies about two inches below the transpyloric plane and cuts the lower part of the body of the third lumbar vertebra and corresponds to the most dependent part of the tenth rib.

Transtubercular plane. Join the tuberosity of the crest of ilium of hip bone of one side with the other by a straight line and this will represent the transtubercular plane and this cuts the upper part of the body of the fifth lumbar vertebra.

Lateral plane. The corresponding lateral planes (right and left) can be outlined by drawing a line perpendicularly upwards from the middle of the corresponding inguinal ligament. In its course it will cut both the transpyloric and the transtubercular planes.

Sterno-ensiform point. This point corresponds to a depression immediately below the sternal insertion of the seventh pair of costal cartilages and can be readily recognised even in fat subjects.

On the backside the portion opposite the abdomen is marked by the conspicuous elevation caused by the erector spinae (sacrospinalis) and extends for about 2½ inches from the midline which forms a conspicuous linear hollow between them.

Lumbar triangle. The base of the lumbar triangle corresponds to the highest point of the iliac crest and its margins are formed by the obliquus externus abdominis in front and the latissimus dorsi behind.

Highest point of iliac crest or the intercristal plane. A transverse line joining the highest points of the two iliac crests passes across the fourth lumbar spine or between third and the fourth lumbar spines; this guide is made use of in performing the lumbar puncture and in counting the lumbar vertebrae.

Deep inguinal ring. The centre of the deep inguinal ring can be represented by a point which lies 1 cm. above the midpoint of a line joining the anterior superior iliac spine and the symphysis pubis.

Superficial inguinal ring. The centre of the superficial inguinal ring can be represented by a point which lies about 1cm. above and the same distance lateral to the pubic tubercle.

Inguinal canal. The inguinal canal can be represented by a line joining the deep to the superficial inguinal ring and measures about 3·7 cm. in length.

Inferior epigastric artery. This can be represented by a line drawn from the mid-point of a line, joining the anterior superior iliac spine to the symphysis pubis, to the umbilicus.

Ligamentum Teres hepatis. It represents the obliterated left umbilical vein and extends from the umbilicus to the left end of the porta hepatis where it ends by joining with the left branch of the portal vein. It can be represented by a line which ascends upwards and to the right from the umbilicus to the lower border of the liver a little to the left of the gall bladder notch opposite the ninth costal cartilage.

The stomach. The *cardiac orifice* lies behind the seventh costal cartilage 2·5 cm. to the left of the median plane and can be represented by two short parallel lines 2 cm. apart, inclining downwards and to the left. The *pylorus* can be represented by two short parallel lines 2 cm. apart on the transpyloric plane about 1/2 an inch to the right. The *lesser curvature* can be represented by a J-shaped line by joining the right margin of the cardiac orifice and the upper margin of the pylorus, the union with the latter taking place immediately below the transpyloric plane. The *fundus* of the stomach corresponds to a line, convex upwards, and drawn from the left margin of the cardiac orifice to a point in the left fifth intercostal space immediately below the nipple, or in the mid-clavicular line. The *greater curvature* of the stomach can be represented by a curved line convex to the left and downwards, drawn from the left

e fundus to the lower margin of the pylorus. In its course it cuts the costal etween the tips of the ninth and tenth costal cartilages.

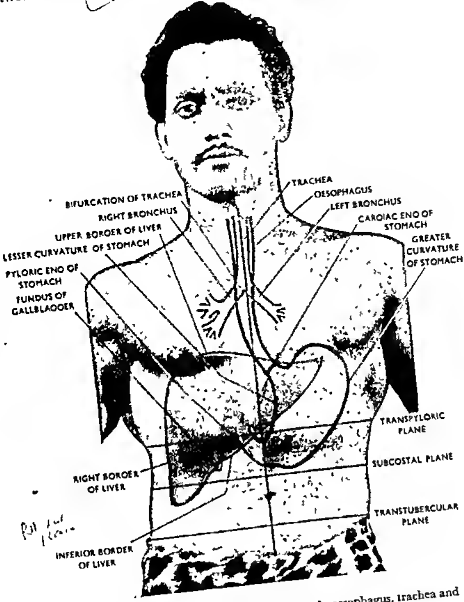

Fig. 900. The surface relations of the stomach, oesophagus, trachea and the bronchi and the liver.

The duodenum. It is about 2·5 cm. wide. It begins immediately above the transpyloric plane 1/2 an inch to the right of the median plane and ascends upwards and to the right for about 2 inches (*First part*) and then descends downwards for about 3 inches on the medial side of the right lateral plane (*Second part*) and then it curves to the left to reach the median plane above the umbilicus (Third part) and finally it ascends upwards and to the left for about 2·5 cm. to end into the duodeno-jejunal flexure 1 cm. below the transpyloric plane and about one inch to the left from the median plane.

The pancreas. Its head can be represented by a curved line that corresponds to the inner border of the first, second and the third parts of the duodenum, its neck can be represented by two lines 3 cm. apart which pass upwards and to the left

behind the pylorus, and its body and tail can be represented by 2 lines 3 cm. apar drawn upwards and to the left for 10 to 12 cm. from the neck.

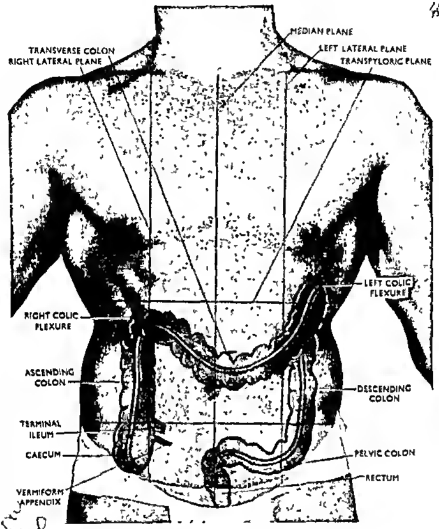

Fig 901. The surface relations of the large intestine

The caecum. It occupies the triangular interval bounded by the right lateral plane, the transtubercular plane and the fold to the groin. It can be outlined by a U-shaped curved line having the convex border directed downwards in this area.

The Iliocolic valve or orifice. It can be represented by two parallel horizontal lines 2 cm. apart or by a point opposite the intersection between the right transtubercular plane and the right lateral plane.

The ascending colon. It can be represented by 2 parallel lines 5 cm. apart which begin from the transtubercular plane immediately on the right side of the right lateral plane and end in the right colic flexure at a point mid-way between the transpyloric plane and the subcostal plane.

The transverse colon. It can be represented by two curved lines 5 cm. apart. It begins in the right hypochondriac region immediately below the transpyloric plane on the right side of the right lateral plane and then descends down-

Posterior femoral cutaneous nerve. Same as sciatic nerve but its lower point corresponds to the inferior angle of the popliteal fossa.

Common peroneal **(Lateral popliteal) nerve.** Take a point at the superior angle of the popliteal fossa, another on the head of the fibula and the third on the lateral aspect of the neck of the fibula. The nerve follows the medial margin of the tendon of the biceps femoris and curve forwards around the neck of the fibula.

Deep peroneal **(Anterior tibial) nerve.** Take a point on the lateral side of the neck of the fibula and another between the tibial tuberosity and the head of the fibula and the third point between the two malleoli and join them together.

S erior extensor retinaculum. It is a thickened band of deep fascia oad and extends from the anterior border of the triangular subcutaneous he lower end of the fibula to the lower part of the anterior border of the

erior extensor retinaculum. It is attached to the anterior part of the urface of the calcaneum and is represented by a band, 1·5 cm. wide, which medially to the dorsum of the foot to the medial side of the extensor digitorum tendon from where it divides into two limbs; the upper limb passes to the l nalleolus while the lower limb passes round the medial margin of the foot in the plantar aspect where it is continuous with the plantar aponeurosis.

Superficial peroneal (Musculocutaneous) nerve. Take a point on the al aspect of the neck of the fibula, another on the anterior border of the neus longus tendon at the junction of the lower and middle-third of the leg, ond this point it becomes subcutaneous. It is drawn by a line directed down- ds and inwards from the first to the second point.

Posterior tibial nerve. Points same as the posterior tibial artery.

The flexor retinaculum of the foot. It is a broad band about 1 inch ide and passes downwards and backwards from the medial malleolus to the medial spec of the heel. Its lower border runs from the medial malleolus to the tubercle of the calcaneum.

THE RADIOGRAPHIC ANATOMY

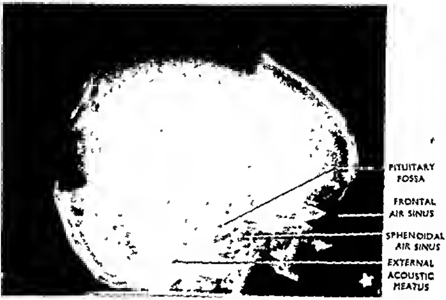

Fig. 920. The lateral radiograph of the head.

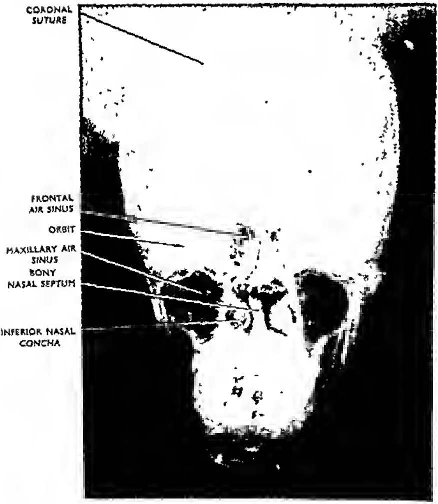

Fig. 922. The lateral radiograph of the neck.
Explanatory notes.—*Note the positions of the cervical spines, hyoid bone, larynx, trachea and the oesophagus*

Fig. 923. The radiograph of the left shoulder joint of a subject of growing age

Explanatory notes.—Note the *line of separation* between the composite upper epiphysis and the diaphysis of the humerus.

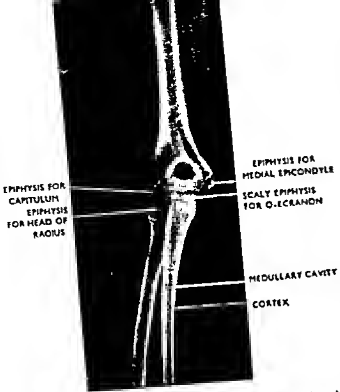

Fig. 924. The antero-posterior radiograph of the elbow joint.

Explanatory notes. Note the scaly epiphysis of the olecranon which is just visible; this epiphysis ossifies at the age of 11 years. Therefore the age of the subject is above 11 years. The epiphysis for the capitulum and the

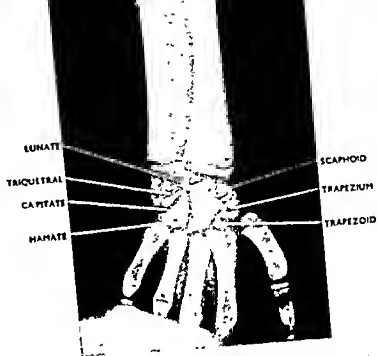

Fig. 925. The antero-posterior radiograph of the wrist, part of the hand and forearm of a boy of 9 years.

Explanatory notes. In this radiograph all the carpal bones except the pisiform bone, which ossifies between tenth and twelfth years, are visualised. Thus the subject appears to be below ten years. The lower epiphysis of the ulna which ossifies between seventh and eighth years is just visible and therefore the age of the subject should be between

Fig 926. The antero-posterior radiograph of the hand and wrist in adducted position.

Explanatory notes. Both the lower epiphyses of the ulna and radius which completely unite with their respective shafts at twentieth year are seen to be partially united. Note also the pisiform bone which ossifies between tenth and twelfth years. Thus the age of this subject would be between twelfth and twentieth years. The epiphyses of the proximal phalanges which completely unite at seventeenth year, are seen to be just short of being completely united. Thus the approximate age of the subject would be between sixteenth and seventeenth years.

Fig. 927. The radiograph of hand and lower forearm of a boy aged 2½ yrs.

Explanatory notes. In this radiograph the lower epiphysis of the radius and the capitate and the hamate bones are visible. Both the hamate and the lower epiphysis of the radius ossify at the age of second year. The triquetral bone, which ossifies at the age of third year, is not visible. Therefore the age of the subject would be between 2 and 3 years.

Fig 928. The excretory pyelogram showing the upper urinary tract.

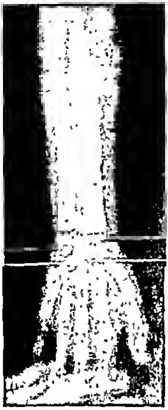

Fig. 929. The antero-posterior radiograph of the forearm and hand

Explanatory notes. Note that the lower epiphysis of the radius, triquetral, hamate and capitate bones are visualized. Other carpal bones are not seen because they are still cartilaginous. The triquetral bone ossifies at the age of third year The lunate bone, which ossifies at fourth year, is not visualised. Therefore the age of the subject would be above three years and below four years.

Fig. 930. The antero-posterior radiograph of the thorax.

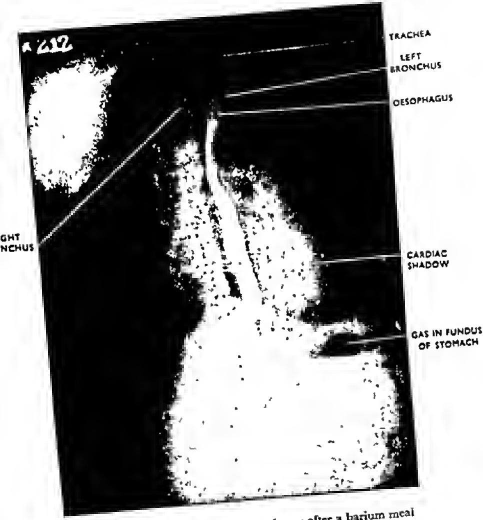

Fig. 931. A lateral skiagram of the thorax after a barium meal showing the oesophagus.

Fig. 932. The cholecystogram of an adult male.

Explanatory notes. The gall bladder is not normally visible after a frank X-Rays and it has been made visible after oral administration of a radio-opaque dye which is eliminated through the biliary passages and collects into the gall bladder which is thus rendered visible by the X-Ray's. Note also the positions of the spines of the lumbar vertebrae and their articular processes.

Fig 933. The radiograph of the stomach and the small intestine after

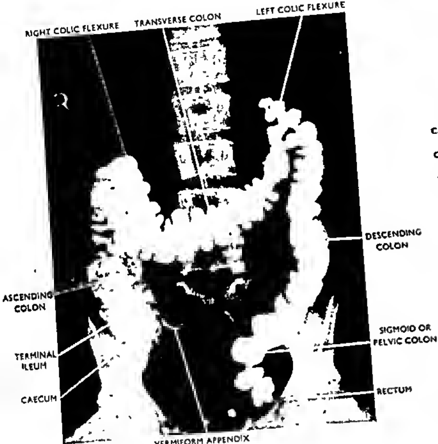

Fig. 934. The radiograph of the large intestine after a barium meal.

Explanatory notes. Note the haustrations, the characteristic features of the large intestine. Also note the long vermiform appendix which is "pelvic" in position.

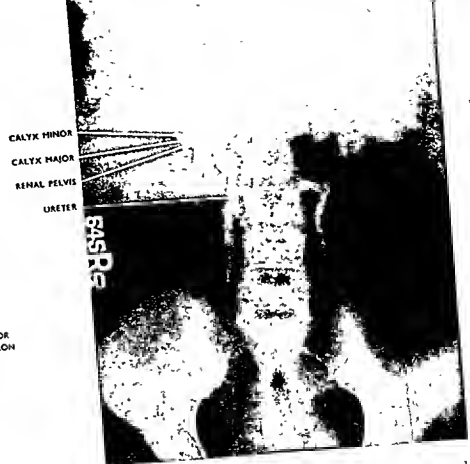

Fig. 935. An excretory pyelogram showing the calices, the renal pelvis and the ureter.

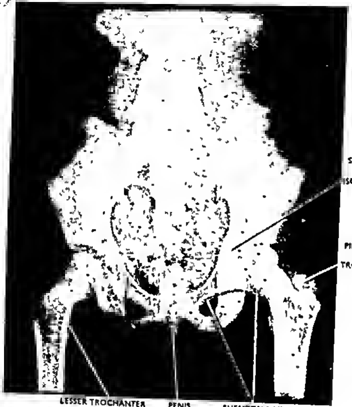

Fig. 936. The antero-posterior radiograph of the pelvis and lower abdomen.

Explanatory notes. Note the Shentons line which forms an uniform curved line between the upper margin of the obturator foramen and the lower margin of theneck of the femur. Note also the lesser trochanter which ossifies between twelfth and fourteenth years. The head of the femur, which completely unites with the shaft between eighteenth and nineteenth years, is seen partially united. Thus the age of the subject would be about eighteenth year.

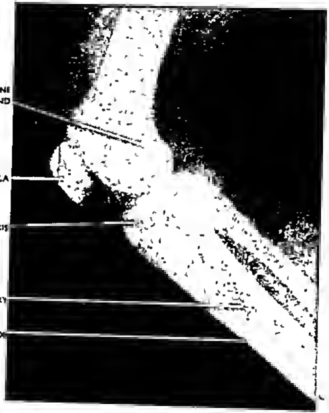

Fig. 937. The lateral radiograph of the knee joint of a young adult.

Explanatory notes. Note the epiphyseal scar at the upper end of the tibia and at the lower end of the femur. Note also the position of the patella in relation to the femoral condyles in semiflexed position of the knee joint.

Fig. 938. The antero-posterior radiograph of the knee of a girl aged 13 years.

Explanatory notes. It appears from the above radiograph that none of the epiphyses at the region of the knee has united. The lower epiphysis of the femur and the upper epiphysis of the tibia unite with their respective diaphysis at twentieth years and therefore the age of the subject is below twenty years. Without additional data definite age in this case cannot be determined.

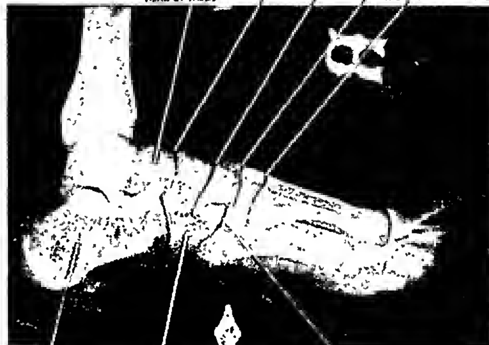

Fig. 939. The lateral radiograph of an adult foot.

Explanatory notes. The talus, navicular, calcaneum and the cuboid bones are well visualised. Due to overlapping shadows the metatarsal bones, except the first and the fifth, are not well de-demarcated. Note the positions of some of the tarsal and tarso-metatarsal joints.

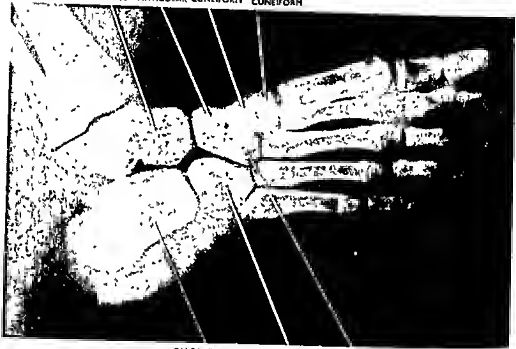

Fig 940. The oblique dorsal radiograph of the foot of a boy of nine years.

Explanatory notes. Note that all the tarsal and metatarsal bones are well-visualised and the joint spaces between them are wider which indicate that the bones are still to grow. Also note that the scaly epiphysis of the calcaneum on its dorsal surface, which appears at about the tenth year, has not appeared and at the same time the epiphyses for the proximal phalanges which appear between 3 and 6 years have appeared. Thus the age of the subject would be between sixth and tenth years.

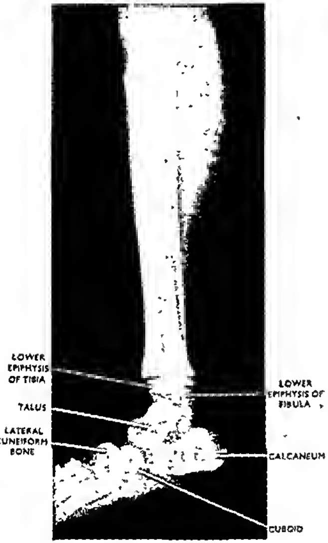

Fig. 941. The lateral radiograph of the foot of a boy of two and a half years.

Explanatory notes. In this radiograph the lower epiphyses of the tibia and the fibula which begin to ossify at second year and at the later part of first year respectively are well-visualised. The navicular bone which begins to ossify at third year is not seen and therefore the age of this subject would be above 2 years but below three years.

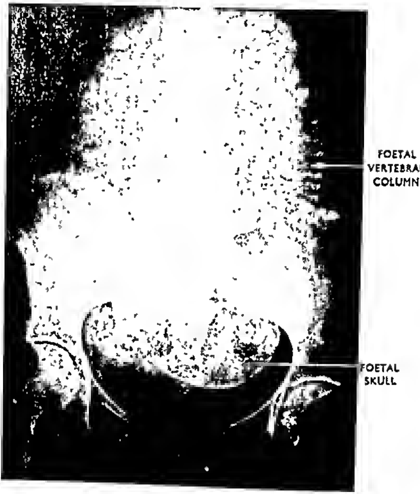

Fig 942. The antero-posterior radiograph of the abdomen of an expectant mother.

Explanatory notes. Note that the foetal skull lies partly within the pelvic cavity of the mother and that the foetal vertebral column is arched into a semi-circle indicating a normal curvature with vertex (normal) presentation.

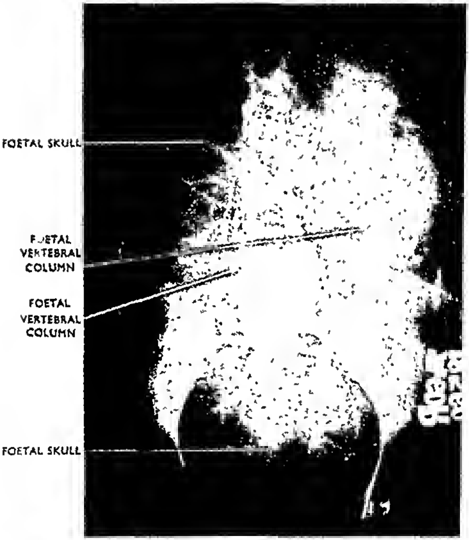

Fig. 943. The antero-posterior radiograph of the abdomen of an expectant mother.

Explanatory notes. Note two foetal skulls, one above and one within the pelvic cavity of the mother. The expectant mother harbouring twin.

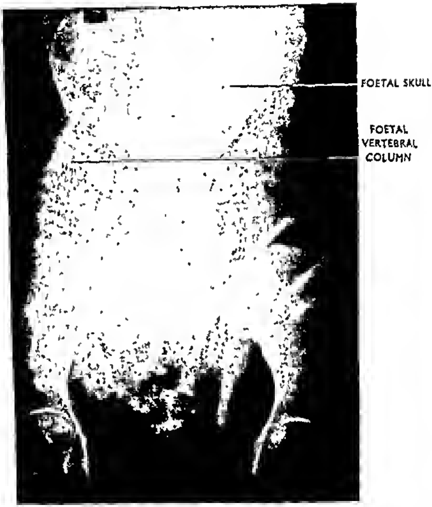

Fig. 944 The antero-posterior radiograph of the abdomen of an expectant mother.

Explanatory notes. Note the position of the foetal skull above and the buttock (breech) within the pelvic cavity of the mother indicating a breech presentation.

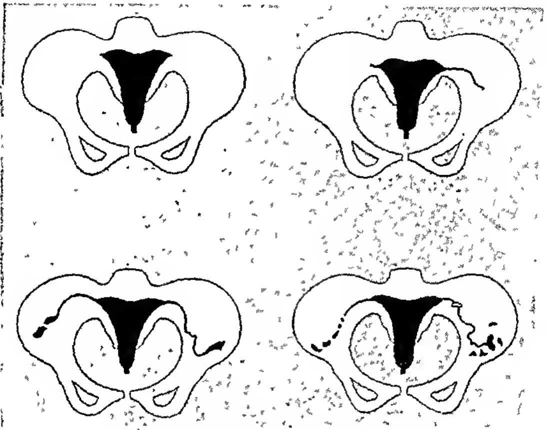

Fig 945. A hysterosalpingograph (Diagrammatic)

Explanatory notes. The first figure on the left side top does not show the injection of the opaque medium into the tubes. The top figure on the right side shows partial injection of the tubes. The first figure on the left side bottom shows complete injection of both the tubes and the figure on the right side bottom shows the opaque medium to reach even the peritoneal cavity.

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